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POLICY ANALYSIS OF THE UPGRADED THIRD GENERATION AIR TRAFFIC CO--ETC(U)
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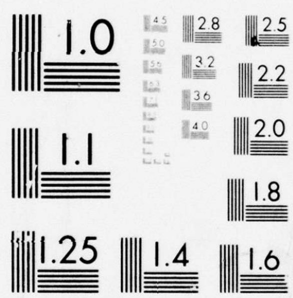


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# POLICY ANALYSIS OF THE UPGRADED THIRD GENERATION AIR TRAFFIC CONTROL SYSTEM

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John M. Rodgers





FINAL REPORT
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U.S. DEPARTMENT OF TRANSPORTATION
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16. Abstract

This report provides a review of costs and benefits of the Upgraded Third Generation Air Traffic Control System (UG3RD) from a systems perspective and also reviews the feasibility and effectiveness of complementary policy strategies. The analysis values the costs and benefits of five alternative systems composed of potential combinations of UG3RD components. For each system, the added cost of airport and airway service was quantified for both the Federal Aviation Administration (FAA) and for airway users. Benefits consisted of increased airport capacity and reduced delay, savings from reduced FAA staff requirements, and improved airway system safety. In addition to estimating costs and benefits of various investments, the study investigates the impacts of airport quotas and peak pricing, increased use of satellite airports, and terminal control areas.

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Various analytical tasks described here draw upon findings of several subordinate research efforts. Estimates of the impact of the Upgraded Third Generation Air Traffic Control System (UG3RD) on air traffic controller productivity are based upon research supervised by Walter Faison, Policy Analysis Division, Office of Aviation Policy, Federal Aviation Administration. The authors therefore wish to acknowledge Mr. Faison's contribution to this analysis. In addition, analyses of airport capacity and safety impacts were performed by The MITRE Corporation under the supervision of Dr. Joseph Matney. Effects of various UG3RD investment options on aircraft and passenger delay were estimated by the staff of Battelle Columbus Laboratories working under the direction of Mr. Robert Rogers. The Transportation Systems Center staff, directed by Dr. Robert Reck, prepared estimates of UG3RD costs. Analyses of air traffic control productivity were drawn from work of Stanford Research Institute conducted by George J. Couluris and econometric analyses directed by Henry Eskew, Administrative Sciences Corporation.

Analysis of the impact of pricing and administrative policy options to complement the UG3RD were undertaken at the Flight Transportation Laboratory at the Massachusetts Institute of Technology under the direction of Professor Robert W. Simpson. The analysis of satellite airport feasibility was supported by Nicholas P. Krull, and Mr. John J. Grocki, Gellman Research Associates. Finally, the General Aviation Operations Research Corporation, directed by Mr. James M. Daniels, completed the analysis of terminal control area (TCA) impacts on general aviation activity.

## EXECUTIVE SUMMARY

### BACKGROUND

The rapid growth of air traffic activity in the past half-century has required major improvements in the capabilities and performance of the air traffic control (ATC) system maintained and operated by the FAA. There is current expansion in both air carrier and general aviation activity and expectations are for an overall aviation growth rate which will result in a doubling of total air traffic activity in a 10-20 year period. The "lead times" in proceeding from new concepts or technology through widespread field implementation of new capabilities are seldom less than ten years, and lend added emphasis to the need for the planning, engineering and development of improvements to the current ATC system.

An organized ATC system began in the 1930's, based primarily on procedural separations and manual handling of flight progress strips. Following World War II, radar surveillance techniques were introduced; during the 1950's, computers were first used to print flight progress strips. These steps comprised the Second Generation ATC System. Further upgrading began in the 1960's and is just now reaching completion in the Third Generation System which is based on computer presentation of aircraft track using the ATC radar beacon system and its associated airborne transponder. The system also includes semi-automated (rather than manual) transfer of control between controller positions and with other ATC facilities. Engineering, developing, and acquisition costs to computerize the present system approached a billion dollars with the 20 Enroute Air Traffic Control Centers and 63 high-density towers having had automated equipment installed.

In 1969, a major study effort by the Department of Transportation Air Traffic Control Advisory Committee (ATCAC) determined that the capability of the Third Generation ATC System would not be adequate to meet the increase in demand forecasted for the late 1970's and beyond, but concluded that further upgrading of the Third Generation System was possible and desirable. The ATCAC report, revalidated in subsequent studies, recommended the direction which the FAA is presently taking in developing the Upgraded Third Generation ATC System (UG3RD). The nine major features proposed for the UG3RD system are:

(1) A Microwave Landing System (MLS) to replace the present VHF Instrument Landing System (ILS).

(2) A high performance radar beacon system with an integral data link (referred to as DABS for Discrete Address Beacon System).

(3) A method of safely assuring separation between aircraft flying on Instrument Flight Rules (IFR) and those operating on Visual Flight Rules (VFR). This can take the form of an airborne Collision Avoidance System (CAS) or a combination ground based airborne system tied into the DABS development and known as automatic Intermittent Positive Control (IPC).

(4) Additional automation of center and tower ATC functions.

(5) Development of a Wake Vortex Avoidance System (WVAS) so that aircraft may be spaced closer together, but still avoid the hazards of wake vortices generated by large aircraft.

(6) A cooperative international trans-oceanic aeronautical satellite development--known as AEROSAT.

(7) Automation and modernization of the services performed by the over 300 Flight Service Stations--known as the FSS Modernization Program.

(8) The development of an Airport Surface Traffic Control (ASTC) system to provide tower controllers at major airports the capability of locating and controlling all transient surface aircraft in any kind of weather.

(9) Widespread implementation of Area Navigation (RNAV) routes.

All major features of the UG3RD are currently in some stage of engineering, development or test, at an annual cost of about $75 million per year. The schedules for these various development efforts are not contingent on all of them being completed and phased into operational use simultaneously; rather, some can be implemented separately and, thus, proceed independently,

while others are interrelated and must follow compatible schedules (DABS/IPC for example). The development philosophy associated with the UG3RD program is the concept of full test and evaluation, prior to commitment for procurement in the operational inventory. Further, cost/benefit analyses of each of the major features are being undertaken to assure that effective implementation decisions can be quantitatively substantiated.

An Office of the Secretary of Transportation (OST) study of the plans for the engineering and development of the UG3RD system was made during 1974.

The OST report recommended continuation of E&D work on the UG3RD. It also requested, however, that the FAA conduct further studies on technical and operational solutions to future ATC problems. The OST requested investigations of future airport and airway scenarios; formulation of more detailed implementation assumptions for specific features of the UG3RD; cost-benefit analyses of both individual UG3RD system components and the overall system; and formulation and evaluation of noncapital policy actions to complement the UG3RD program. In response, the FAA initiated a comprehensive analytical effort in early 1975 with the following parts:

(1) Baseline and Implementation Scenarios

(2) UG3RD System Cost-Benefit Analysis

(3) Productivity Assumptions

(4) Transition Planning

(5) Complementary Policy Strategies

(6) Technical and Cost-Benefit Analyses of Individual UG3RD Features

This report summarizes the analyses of (1) the costs and benefits of the UG3RD from a systems perspective, and (2) the feasibility and capability of complementary policy strategies which may enhance overall system performance in concert with the UG3RD or independently.

## FINDINGS AND CONCLUSIONS

The alternative UG3RD configurations investigated in the present study, when compared with a scenario of no new action, provide benefits significantly in excess of costs. Benefit-cost ratios range between 10:1 and 19:1 assuming a high level of airline quality DABS/IPC avionics in the fleet. The ratios increase to between 17:1 and 22:1 if DABS/IPC avionics is assumed to be preponderantly composed of standard and medium quality equipment. The system having the largest present value of net benefits is one composed of automated WVAS, advanced metering and spacing, conflict resolution and control message automation, and DABS. Further, the introduction of IPC produces substantial improvements in aviation safety through the prevention of mid-air collisions and collisions with the terrain.

In all alternatives analyzed, reduction of aircraft and passenger delay produced the largest benefit values. The values associated with delay reduction were at least five times as great as all other types of benefits combined. Safety benefits are associated with all UG3RD systems investigated, but in the simpler systems safety benefits are limited to provision of backup accident prevention capability to ATC safety features already in existence or which are presently being implemented. The introduction of IPC will, however, provide significant new accident prevention impacts.

The present discounted value of UG3RD costs range from $391 million for the most modest configuration to $1.6 billion for the most extensive configuration.

In addition to the technical features of the UG3RD, there was an evaluation of certain noncapital or relatively low capital policy strategies which might provide complementary benefits. The first strategy examined was the use of pricing and administrative alternatives such as peak pricing and quotas, to discourage peak hour airport use. At the majority of air carrier airports most of the delay problem is experienced during these peak traffic periods. This analysis finds that while a schedule of peak pricing and quotas would not transform the daily distribution of flights into a perfectly rectangular pattern, it could effectively smooth the peaks, spreading traffic more uniformly to off-peak hours. This redistribution of traffic can significantly reduce congestion and delay throughout the airport system.

Among alternative airport development options examined in this report, it is concluded that air carrier delays would be minimized in a system incorporating both UG3RD capacity improvements and a peak-load pricing schedule. Comparing capital and noncapital development alternatives, the analysis indicates that, peak pricing and quotas at the top 25 commercial airports would reduce air carrier delays more than hardware features of the UG3RD.

There are economic and institutional constraints, however, limiting the implementation of these policy strategies on a widespread scale. For example, the optimum fare schedule necessary to shift air carrier traffic away from peak demand periods is not presently known. Nor have all the possible issues which might confront the FAA, airport sponsors and the airline been satisfactorily resolved. Perhaps more importantly, a peak pricing strategy would represent a departure from the traditional concept of free access to aviation facilities and would probably generate formidable opposition. The pricing and administrative alternatives reviewed in this report may emerge as more realistic options for the national airspace system when these constraints are overcome.

The second policy option examined in this report was the expanded use of satellite airports in major metropolitan areas. This alternative has often been considered as an efficient method of relieving the traffic increasing congestion at primary air terminals. While numerous constraints impose limits on the overall number of potential satellite candidates, this report finds that maximum use of airports which do offer potential could significantly relieve air traffic delay, easing, perhaps, requirements for capacity improvements at some of the major airports.

The best prospects for satellite use were indicated for propeller-driven and smaller turbine airplanes; few facilities studied appeared to have potential to absorb additional flights of large jet traffic. Significant diversions of any traffic to satellite airports are not anticipated, however, without additional incentives drawing (or forcing) traffic from the primary terminals.

Finally, the analysis evaluated a proposal to expand the use of Terminal Control Areas (TCA) to facilitate traffic control in the airspace surrounding major airports. While

the survey undertaken for this report found no evidence that expanding the use of TCA's would have a major impact on the growth of terminal area traffic, five years of experience with the TCA indicates that is is an effective way of providing safe separation of traffic in the terminal area.

RECOMMENDATIONS

- Configurations of the UG3RD air traffic control system consisting of WVAS, automation, and DABS/IPC at terminals and enroute centers should be implemented as soon as possible.

- A coordinated budget and developmental program should be established within the FAA to expedite early implementation of the UG3RD.

- The development of DABS/IPC should continue in order to accrue full-benefits of the UG3RD system.

- Continued emphasis in the engineering and development program should be given to reducing user acquisition costs of DABS/IPC avionics. To the extent that user costs are reduced, the net benefit of the program will increase as will user acceptance.

- Encourage diversion of air traffic from primary hub airports to satellite airports by improving air navigation facilities at satellite airports. This can be accomplished in part by modifying navigation facilities establishment criteria to reflect full system benefits of satellite airport use.

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## 1.0 Introduction

Rapid increases in the use of airport and airway facilities confronted the FAA during the last half of the 1960's. Costly delays, restrictions on airport use, and congestion resulted, coupled with increased difficulty in controlling the flow of traffic while maintaining high safety standards. Because of this situation, the Air Traffic Control Advisory Committee (ATCAC) was created by the Department of Transportation. ATCAC concluded that the planned Air Traffic Control (ATC) system would be inadequate to handle traffic beyond 1980 and went on to identify needed future improvements. The ATCAC recommended system, termed the Upgraded Third Generation System (UG3RD), was intended for use during the 1980's and beyond. Based on the ATCAC Report [75] and endorsements by two other independent groups, 1/ the following UG3RD engineering efforts 2/ were undertaken by the FAA:

1. Wake Vortex Avoidance System (WVAS)
2. Discrete Address Beacon System (DABS)
3. Intermittent Positive Control (IPC)
4. Upgraded Air Traffic Control Automation
5. Airport Surface Traffic Control (ASTC)
6. Microwave Landing System (MLS)
7. Area Navigation (RNAV)
8. Flight service Stations (FSS)
9. Aeronautical Satellites (AEROSAT)

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1/ The joint DOT/NASA Civil Aviation Research and Development Study Team and the Air Transportation Panel of the Presidential Scientific Advisory Committee.

2/ Detailed descriptions of these programs are provided in Chapter 2.

Halfway through the planned UG3RD Engineering and Development (E&D) program, the Office of the Secretary of Transportation (OST) conducted a review of developments and published a staff study [99] in August of 1974.

The OST report recommended continuation of E&D work on the UG3RD. It also requested, however, that the FAA conduct further studies on technical and operational solutions to future ATC problems. The OST requested investigations of future airport and airway scenarios; formulation of more detailed implementation assumptions for specific features of the UG3RD; cost-benefit analyses of both individual UG3RD system components and the overall system; and formulation and evaluation of noncapital policy actions to complement the UG3RD program. In response, the FAA initiated a comprehensive analytical effort in early 1975 with the following parts:

1. Baseline and Implementation Scenarios
2. UG3RD System Cost-Benefit Analysis
3. Productivity Assumptions
4. Transition Planning
5. Complementary Policy Strategies
6. Technical and Cost-Benefit Analyses of Individual UG3RD Features

## 1.1 The Problem

The UG3RD program has progressed to the point where decisions on implementation are pending. Because of potential technical interdependence and possible unique system effects of component combinations, UG3RD investment decisions should be considered from a system aspect, as well as from the perspective of individual components. The OST recommended [99] that an overall cost-benefit analysis be conducted of the UG3RD prior to implementation of the system. Also, adequate airport and airway long-run planning requires consideration of policy strategies which may complement capabilities provided by the UG3RD. OST recognized this requirement and requested [99] analyses of potential complementary strategies.

## 1.2 Objective of Study

The purpose of this report is to (1) analyze the costs and benefits of the UG3RD from a systems perspective, and (2) report on the feasibility and capability of complementary policy strategies which may enhance overall system performance in concert with the UG3RD or independently. These analyses, coupled with the results of cost-benefit analysis of individual UG3RD components, should facilitate implementation decisions for the UG3RD.

## 1.3 Approach

The present study integrates research outputs from the five-part FAA response to the August 1974 OST staff study and recommendations on UG3RD developments [99].

### 1.3.1 Cost/Benefit Analysis

Costs and benefits of a UG3RD "system" versus continuation of the present system were estimated to help evaluate potential investments. The analysis draws on forecasts and descriptions of future aviation activity as presented in UG3RD Baseline and Implementation Scenario [96]. Costs and benefits were estimated for five alternative configurations of equipment selected from nine UG3RD component programs. For each alternative UG3RD configuration, the additional or marginal cost of airport and airway services associated with UG3RD implementation was quantified for both the Federal Aviation Administration (FAA) and for airway system users.

Benefits estimated by the study consist of increased airport and airway capacity, reduced delay at 30 airports, possible reduction in delay costs attained independent of delay reduction, reduced FAA staff requirements, and improved airway system safety. Additional information is also provided on the energy and pollution impact of UG3RD implementation.

The five alternative UG3RD systems analyzed in this cost-benefit analysis represent a broad range of costs and technical capability. An attempt was made in defining each alternative, to select a component combination which represented an integrated system with synergistic effects--that is, where there was technical interdependence such that the value of the functional capability achieved by combination was greater than the sum of benefits that would be obtained from separate installation of each individual component. Further, the selection of alternatives attempted to survey a range of potential system cost and benefit levels and to avoid duplication of research undertaken by on-going cost-benefit analyses of individual UG3RD components.

### 1.3.2 Complementary Policy Strategies

The analysis of complementary policy strategies examines the potential effectiveness of three different actions:

1. The use of pricing and administrative options to allocate scarce airport capacity and redistribute the time pattern of airport usage.

2. Increased utilization of satellite or secondary airports to relieve congestion at major commercial terminals.

3. Increasing the size and number of Terminal Control Areas (TCA's).

The analysis of pricing and administrative policy options provides data on terminal delays and delay reductions under four different scenario assumptions:

1. Continuation of present ATC system facilities and procedures--the base case.

2. The introduction of quotas and peak-load pricing to redistribute air traffic demand.

3. The introduction of UG3RD technological features.

4. The introduction of peak pricing and quotas in concert with the UG3RD system.

For the analysis of the second complementary policy strategy, 375 candidate satellite airports in the top 23 large hub areas were identified and evaluated as to capacity for off-loading or relieving air traffic congestion at the primary large hub airports. Results are presented in terms of the delay that would be experienced at major terminals, first assuming no diversion to feasible satellite airports, and then assuming maximum diversion of operations to satellite airports.

The final complementary policy investigated--increasing the size and number of terminal control areas--focuses on the restrictive impact that terminal control area (TCA) regulations have on general aviation terminal activity. Analytical procedures used in this evaluation consisted of delineation of user population differences to infer likely effects on general aviation terminal usage.

## 1.4 Organization of the Report

Chapter 2 briefly describes potential components of the UG3RD system. The remainder of the chapter defines alternative UG3RD configurations evaluated through system cost-benefit analysis and discusses the rationale for selecting the various alternatives. Costs, benefits, and estimating methods are outlined in Chapter 3. Results of the system cost-benefit analysis are given at this point and detailed cost-benefit tabulations related to the system cost-benefit analysis are contained in Appendix A. Chapter 4 evaluates noncapital options to relieve terminal area congestion that could be pursued along with capital options embodied in the UG3RD. Chapter 5 summarizes major study findings and conclusions, and recommendations are given in Capter 6. Several appendices describe the airport network model referenced in Chapter 4 and the calculation of flow control benefits.

Because this report is intended to summarize several major analytical efforts, much of the specific technical detail on estimation methods and procedures is omitted. Supporting detail is, however, contained in the following separate documents:

1. UG3RD Baseline and Implementation Scenario [96]
2. Estimation of UG3RD Costs [95]
3. Estimation of UG3RD Capacity Impacts [65]
4. Estimation of UG3RD Delay Reduction [56]
5. Estimation of UG3RD Productivity Impacts [94]
6. Estimation of UG3RD Safety Benefits [60]
7. Airport Quotas and Peak-Hour Pricing: Theory and Practice [48]
8. Airport Quotas and Peak-Hour Pricing: Analysis of Airport Network Impacts [26]
9. Satellite Airports: Analysis of Development Potential [25]
10. Analysis of the Impact of Terminal Control Area (TCA) Implementation on General Aviation Growth [80]

Analyses contained in the present and above listed publications are direct responses to study requests made by the OST in the "Action Summary," Review of Upgraded Third Generation Air Traffic Control System Developments [99]. UG3RD Baseline and Implementation Scenario fulfills Item I--"define one or more aviation system and facility implementation scenarios." The present volume, along with Estimation of UG3RD Capacity Impacts, Estimation of UG3RD Delay Reduction, Estimation of UG3RD Productivity Impacts, and Estimation of UG3RD Safety Benefits are provided in response to that part of "Action Summary," Item II which requests an overall cost-benefit assessment of the UG3RD system. Also, Estimation of UG3RD Productivity Impacts constitutes a preliminary input to the cost-benefit analysis of proposed automation plans requested in "Action Summary," Item V. Finally, the present volume, along with its supporting documents on airport quotas and peak pricing, development of satellite airports, and the impact of TCA's is provided in response to "Action Summary," Item XI, dealing with complementary policy strategies.

## 2.0 Components of the UG3RD System

Improvements to the present Third Generation Air Traffic Control System are divided into nine component programs. A brief discussion of each program is provided below. Following this, a description is provided of the alternative configurations of components analyzed by this study.

### 2.1 Component Descriptions 1/

#### 2.1.1. Wake Vortex Avoidance System (WVAS)

A major obstacle to increasing airport capacity is caused by safety requirements associated with aircraft wake vortices. These vortices, a pair of counter rotational air flows, are left in the wake of all aircraft in flight. Vortices from large aircraft constitute severe hazards to other aircraft, particularly smaller ones, which encounter them. In the absence of means to detect or predict wake vortices, the FAA has maintained safety by increasing Instrument Flight Rule (IFR) separation standards from 3 nautical miles to at least 5 nautical miles for lighter aircraft following heavy aircraft.

To reduce the terminal aircraft separation requirements imposed by wake vortices, two complementary systems are being developed by the FAA. The first system, using meterological equipment and a microprocessor, will provide predictions on the motion and lifetime of vortices. The second system would use vortex sensing equipment to actually determine the presence of vortices. For the present study, both the prediction and sensing capabilities are assumed to be implemented simultaneously. The system cost-benefit analysis does, however, make two different assumptions about how WVAS will function. Under one assumption --manual WVAS--information is only provided to the controller who maintains separation standards. Alternatively, an automated WVAS is assumed where information is provided to a computer which establishes separation standards in accordance with metering and spacing demand.

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1/ Material in this section is based on descriptions contained in An Overview of Plans and Programs for the Development of the Upgraded Third Generation Air Traffic Control System [99] and Estimation of UG3RD Costs [95].

### 2.1.2 Discrete Address Beacon System (DABS)

Position and identification information on most controlled aircraft is obtained by means of radar surveillance. The Air Traffic Control Radar Beacon System (ATCRBS) derives this information using ground based facilities to scan the airspace and obtain tracking data by interrogating transponders (radio beacon equipment) located in aircraft under surveillance. The ATCRBS system is presently subject to deficiencies. There are situations when an aircraft fails to respond to interrogation signals (missed replies); split targets can appear on radar screens when only one really exists; and the transponder can be confused when simultaneously interrogated by two or more ground stations. Finally, target images can become mixed (termed "synchronous garble") when two or more aircraft fly in certain related portions of airspace.

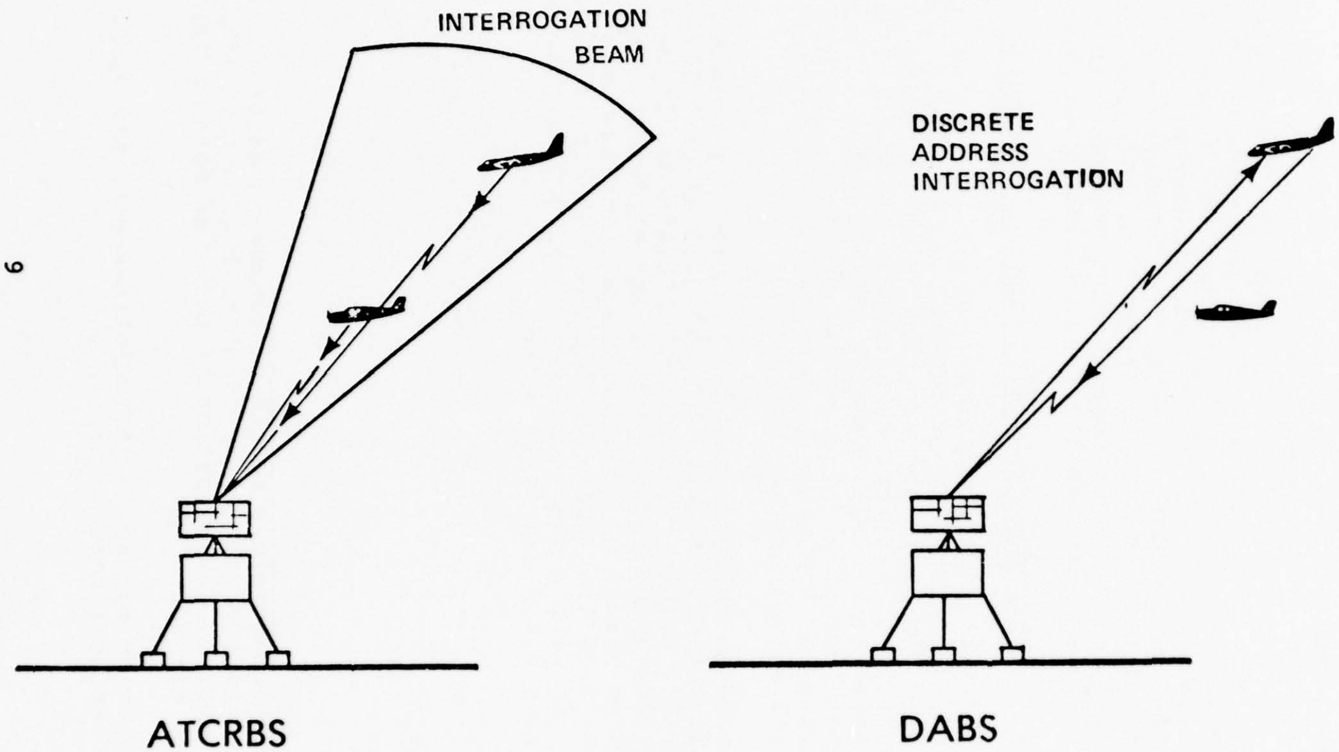
The Discrete Address Beacon System is an evolutionary replacement to ATCRBS. It is intended to reduce all of the present deficiencies associated with ATCRBS. DABS is also uniquely oriented toward elimination of "synchronous garble" and provision of capability, in combination with the Intermittent Position Control element of the UG3RD, for an automatic ground based collision avoidance system.

As presently conceived, DABS will function by selectively interrogating each specific aircraft. The subject aircraft will be addressed with a permanent address code. In turn, the aircraft will reply to its code. This differs from ATCRBS where all aircraft within the beamwidth of the antenna reply to generalized interrogation. See Figure 2.1. DABS will also include an integral data link capability using digital message formats to convey certain information normally exchanged via voice.

Implementation of DABS requires improved ground facilities in the form of antennas, a new receiver system, and data transmission and processing capability. Only the transmission and data processing capability--such as radio channel management, DABS reply processor, ATCRBS reply correlator--are unique to DABS. Other improvements are anticipated as part of the current ATCRBS improvement program. Beyond the ground equipment, DABS requires aircraft to be equipped with a DABS transponder.

Figure 2.1

ATCRBS—DABS COMPARISON



### 2.1.3 Intermittent Positive Control (IPC)

Elimination of midair collisions is a major FAA goal. Intermittent Positive Control, in conjunction with DABS, is intended to provide a new collision avoidance service. The IPC service will operate using the DABS system to assess and to communicate separate commands. To participate in the service, aircraft must be equipped with the DABS transponder and an IPC message display unit. Using the DABS surveillance system, IPC computers will track aircraft, identify collision threats, and generate collision warnings and maneuver commands for automatic transmission via DABS data link to the message display in the aircraft.

### 2.1.4 Upgraded Air Traffic Control Automation

Two major challenges confronting the present ATC system are the physical capacity of controllers to handle traffic and the need for increased accuracy in the metering 2/ and spacing 3/ of aircraft at terminals and enroute in order to increase the overall capacity of the system to handle traffic without increased delay. These problems, and others, are being addressed by FAA programs to increase the automation of traffic control using computer technology.

Expanded automation has been proposed for both terminal and enroute air traffic control activities. These programs generally involve significant software development coupled with some augmentation of existing hardware by the FAA. The advanced phases of automation are integrated with the use of a DABS data link and will require that controlled aircraft be equipped with a DABS transponder and IPC display (see Sections 2.1.2 and 2.1.3 above).

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2/ Metering refers to the placement of aircraft on an airway segment or runway approach path in a regulated flow. It involves determination of both the total number and sequence of aircraft.

3/ Spacing refers to the maintenance of minimum separation distances between aircraft.

For purposes of the present study, proposed automation development has been dichotomized into (1) development necessary to provide flight data distribution and basic aircraft metering and spacing capability to the controller and (2) development of advanced metering and spacing capability, conflict resolution, and control message automation (DABS and IPC integration). Accompanying both levels of terminal and enroute automation is the provision of centralized traffic management often termed "flow control." Information on weather conditions and traffic demand at congested facilities will be analyzed by computer to determine alternative routes and facilitate decisions regarding delaying departures.

### 2.1.5 Other System Components

Five other components are generally also grouped into the UG3RD ATC system. Airport Surface Traffic Control (ASTC) is a combination of new radar ground surveillance equipment and computer augmented displays designed to improve surveillance data available to ground controllers and thereby increase the efficiency of aircraft movements on the ground at major terminals. To improve instrument landing capabilities, a Microwave Landing System (MLS) involving both new FAA ground facilities and new aircraft avionics, has been developed and prototypes are being built and tested. Increased navigation capability providing horizontal, altitude and time data is obtainable from a technique known as Area Navigation (RNAV). RNAV requires only small marginal investments by the FAA in the form of supplementary navigation aids, modification of existing aids, and modification of terminal and enroute control automation (software), but requires significant improvements in aircraft navigational equipment. Under proposed UG3RD developments, flight service stations (FSS) will be automated and the use of unattended pilot self-briefing terminals will be exploited. Finally, AEROSAT is a program aimed at exploring the use of satellites for improving oceanic ATC communications and providing surveillance information to reduce oceanic air separation standards and otherwise improve oceanic traffic management.

## 2.2 UG3RD System Alternative Configurations

The nine individual programs which comprise the UG3RD ATC system can be installed either separately or in conjunction with other elements resulting in over 500 possible combinations of equipment. 4/ If the variable "equipment site" is considered, the number of potential combinations is expanded by many orders of magnitude. It is therefore desirable to limit the number of possible combinations to a small group of alternative UG3RD configurations for further analysis. The alternative UG3RD configurations should concentrate on the system aspect of proposed UG3RD ATC development and bound the ranges of possible program costs and benefits. Five guidelines were used to select UG3RD hardware options for analysis as follows:

1. Configurations should be technically feasible.

2. Configurations should be limited to those where synergistic benefit effects are likely to occur or where component interdependency exists. Synergism refers to cooperative action of two discrete elements such that the total effect is greater than the sum of the two effects taken independently.

3. Alternative configurations should provide a range of different types and levels of functional benefits.

4. Alternative configurations should provide a range of different total system cost levels.

5. Alternative siting combinations should indicate the sensitivity of UG3RD costs and benefits to changes in the scope of program implementation.

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4/ In general, the number of combinations of n things taken r at a time is given by:

$$\frac{n}{r!\ (n-r)!}$$

In the present case r may assume any value between 1 and 9. The total number of possible combinations is given by:

$$\sum_{r=1}^{9} \frac{9!}{r!\ \ (9-r)!}$$

Based on criteria enumerated above, five separate configurations of UG3RD equipment and sites have been evaluated. These configurations, along with remarks on the selection, are listed in Table 2.1. Table 2.2 provides additional details on siting assumptions. The configurations are numbered 1 through 5 in order of ascending technical capability and cost (see Chapter 3 for cost data).

Configuration 1 is the most basic system. It is oriented toward increasing airport capacity and reducing aircraft delays. Airport capacity may be defined in at least two separate, but related ways. First, capacity may be considered as the maximum number of aircraft which can be processed per unit of time through a given runway or airway system under conditions of continuous aircraft demand. Alternatively, a second concept of capacity gives explicit consideration to the quality of service in terms of delay encountered. Under this concept, capacity becomes the maximum number of aircraft which can be accommodated given a constraint that average delay is not to exceed a fixed length of time. Configuration 1 increases capacity by raising the maximum number of aircraft which can be handled per hour by a given runway system and also reduces average delays per aircraft. These concepts are discussed further in Chapter 3.

Beyond having effects on airport capacity and delay, Configuration 1 may also increase controller productivity through the automated distribution of flight data. Productivity is the relationship between inputs to the air traffic control process in the form of people and equipment and the output of the process--takeoffs, landings, and aircraft handled. Increased productivity in the present study refers to an increase in the ratio of output (aircraft operations) to the number of air traffic controllers. Thus, either fewer people are required to handle the same number of operations after a productivity increase or the same number of people can handle more traffic activity.

TABLE 2.1
ALTERNATIVE UG3RD SYSTEM CONFIGURATIONS
EVALUATED BY SYSTEM COST BENEFIT ANALYSIS

| Configuration Number | Component Composition | Siting Assumptions | Remarks on Selection |
|---|---|---|---|
| 1 | WVAS – Manual<br>Automation – Basic<br>Metering & Spacing,<br>Data Distribution | Top 30 air carrier terminals<br>All enroute centers | Most basic synergistic system with potential benefits of increased airport and airway capacity and some increase in controller productivity. |
| 2 | WVAS – Automated<br>Automation – Advanced<br>metering & spacing,<br>data distribution,<br>conflict resolution,<br>control messages<br>DABS | Top 30 air carrier terminals<br>All enroute centers<br>DABS at 100 sites | System embodies the highest envisioned level of airport and airway capacity improvement, major increases in controller productivity, and possible safety effects. |
| 3 | WVAS – Automated<br>Automation – Advanced<br>metering & spacing,<br>data distribution,<br>conflict resolution,<br>control messages<br>DABS | Top 30 air carrier terminals<br>All enroute centers<br>DABS at 300 sites | Same as configuration 2 except wider DABS coverage is provided |
| 4 | WVAS – Automated<br>Automation – Advanced<br>metering & spacing,<br>data distribution,<br>conflict resolution,<br>control messages<br>DABS, IPC | Top 30 air carrier terminals<br>All enroute centers<br>DABS & IPC at 100 sites | System embodies the highest envisioned level of airport and airway capacity improvement, increases in controller productivity and significant collision avoidance benefits. |
| 5 | WVAS – Automated<br>Automation – Advanced<br>metering & spacing,<br>data distribution,<br>conflict resolution,<br>control messages<br>DABS, IPC | Top 30 air carrier terminals<br>All enroute centers<br>DABS & IPC at 300 sites | Same as configuration 5 except wider DABS/IPC average is provided. |

TABLE 2.2

UG3RD EQUIPMENT
SITING ASSUMPTIONS

WVAS and Terminal Automation - Configurations 1 through 5

Chicago O'Hare (ORD)
Atlanta International (ATL)
Los Angeles (LAX)
John F. Kennedy International (JFK)
San Francisco (SFO)
La Guardia (LGA)
Miami (MIA)
Washington National (DCA)
Boston (BOS)
Denver (DEN)

Pittsburgh Greater (PIT)
Detroit Wayne (DTW)
Dallas Love Field (DAL)
St. Louis International (STL)
Philadelphia (PHL)
Newark (EWR)
Minneapolis Wold Chamber (MSP)
Cleveland Hopkins Intl (CLE)
Dallas Fort Worth 2 (DFW)
Houston International (IAH)

Honolulu (HNL)
Memphis (MEM)
Seattle Tacoma International (SEA)
Kansas City International (MCI)
New Orleans Moisant (MSY)
Tampa (TPA)
Las Vegas (LAS)
Indianapolis (IND)
Phoenix (PHX)
Covington Gr. Cinn (CVG)

DABS/IPC equipment - Configurations 2 and 4

Thirty terminals listed above, concentration of remaining remaining units to provide complete center area coverage in one third of the enroute centers.

DABS/IPC equipment - Configurations 3 and 5

Thirty terminals listed above, complete center area coverage in all enroute centers.

Safety benefits, in terms of reduced aircraft accidents and fatalities are a secondary feature of Configuration 1. As will be discussed in Chapter 3, many of the safety benefits for this configuration take the form of back-up to safety measures already present or planned under the current air traffic control system.

Configurations 2 and 3 were selected for analysis because the advanced automation of controller functions and improved surveillance capability which are embodied in the configurations should have the maximum impact on airport capacity. Another consideration in selecting these particular configurations was a desire to estimate the likely combined impact of advanced automation and DABS on controller productivity and aviation safety in the absence of IPC. Under these options the basic role of air traffic controllers shifts toward monitoring of the automated system rather than providing direct personal control of all aircraft.

Changes in aviation safety produced by the introduction of IPC are the focus of Configurations 4 and 5. These configurations represent the fullest potential development of aircraft control technology envisioned for the UG3RD ATC system.

None of the configurations analyzed include ASTC, MLS, RNAV, FSS, or AEROSAT components because these items were not considered to produce synergistic effects. Decisions on potential interaction are based on results of individual component cost-benefit studies [16,39,40,68, and 73] and descriptions of potential technical interdependency published by the Office of Systems Engineering Management, FAA [97]. Potential UG3RD combinations containing elements excluded from the system cost-benefit analysis can be evaluated by adding the costs and benefits of the excluded components to results given in the present study. Costs and benefits of excluded components are obtainable from concurrent cost-benefit studies of individual components.

## 3.0 Costs and Benefits of UG3RD

This chapter initially describes costs and benefits associated with implementation of the UG3RD ATC system and techniques for estimating their respective values. The remainder of the chapter is then devoted to presentation and analysis of estimates for five alternative configurations of the UG3RD ATC system. Further details of cost and benefit estimating procedures are provided in separately published supporting working papers:

1. UG3RD Baseline and Implementation Scenario [96].
2. Estimation of UG3RD Costs [95].
3. Estimation of UG3RD Productivity Impacts [94].
4. Estimation of UG3RD Capacity Impacts [65].
5. Estimation of UG3RD Delay Reduction [56].
6. Estimation of UG3RD Safety Benefits [60].

## 3.1 Classification of Costs and Benefits

### 3.1.1 Benefits

It is anticipated that the UG3RD system will provide the following benefits:

1. Increased airport and enroute capacity resulting in reduced aircraft and passenger delay.
2. Reduced delay costs due to a shift of airborne delay to ground delay.
3. Increased output of FAA air traffic control personnel.
4. Increased aviation safety
5. Reduced energy consumption and air pollution.

All of the potential types of benefits associated with the UG3RD ATC system have been cited in conjunction with previous economic analyses of air traffic control. For example, see "Civil Aviation Expenditures", Gary Fromm [23], "Benefits", Aviation Cost Allocation Study Working Paper Number 9 [98], and Review of Upgraded Third Generation Air Traffic Control System [99].

### 3.1.1.1. Increases in Airport Capacity and Decreases in Delay

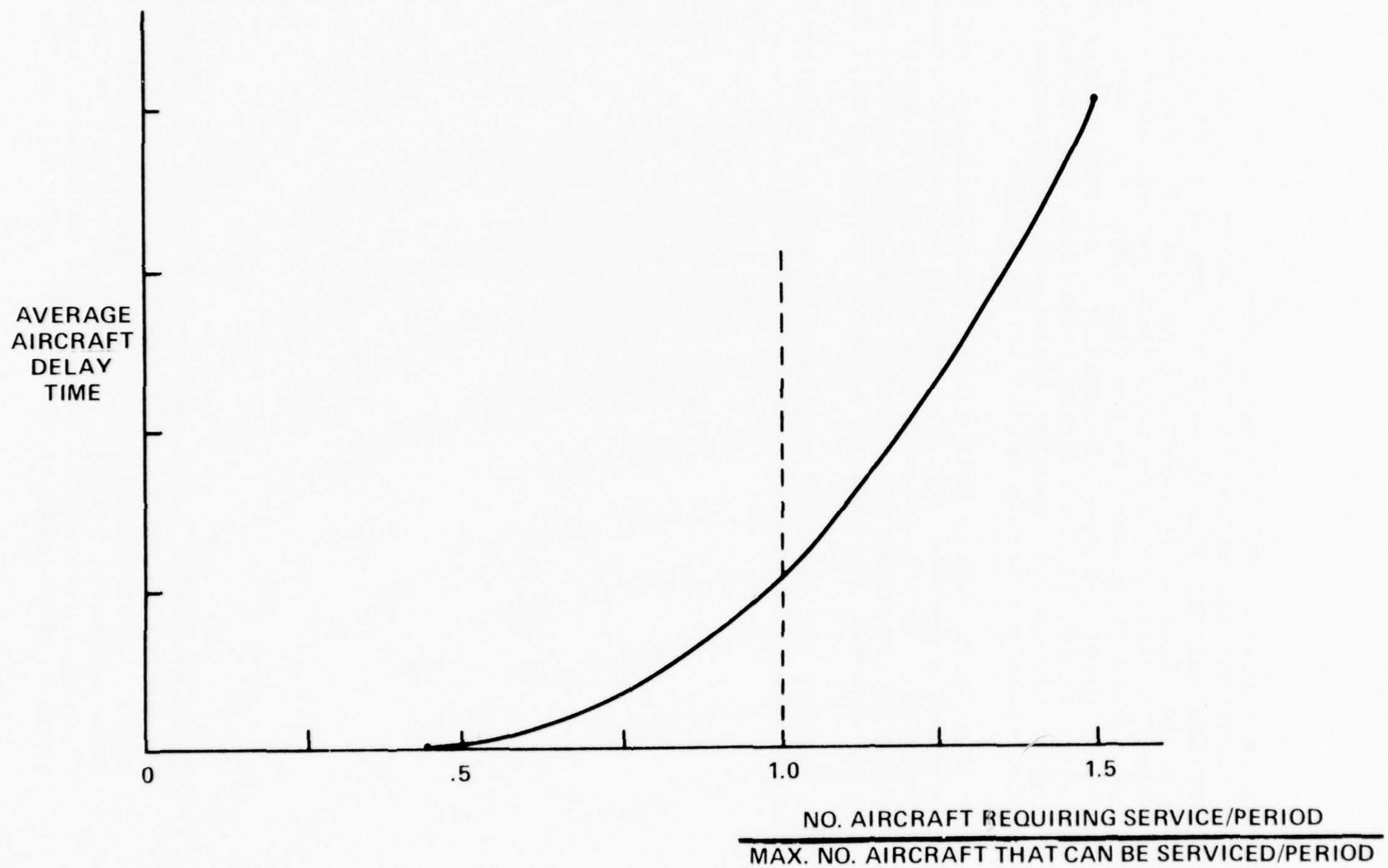
Airport and airway capacities may be defined as the maximum number of aircraft which can be processed per unit of time through a given runway or airway system under circumstances where there is always an aircraft ready to enter the system. This definition takes the form of an hourly maximum rate for specified conditions of fleet mix, wind and other weather conditions. Unfortunately, defining capacity as the maximum number of aircraft which can be handled per hour focuses solely on the physical ability to maintain throughput of aircraft. It does not reflect the related phenomenon of delay. Namely, as the number of aircraft demanding service per unit of time approaches the maximum number which the system can physically handle, aircraft ready for service experience delays of increasing duration before they are able to enter the process. This relationship is illustrated in Figure 3.1. A delay constraint is therefore sometimes incorporated in the definition of capacity. For example, the capacity of the system may be stated as 100 aircraft per hour with average aircraft delay less than 6 minutes per aircraft. 1/ This form of capacity definition is useful when trying to determine the minimum delays which may be associated with a given throughput of aircraft at a terminal.

Given projections of future traffic growth at major air terminals [96], and data on present airport capacity expressed in terms of maximum operations per hour [65], total delay to approaching and departing aircraft is projected to increase from 31 million minutes per year at the 30 largest air carrier terminals in 1975 to 460 million minutes per

1/ A standard of "6 minutes annual average aircraft delay" is sometimes used as the highest delay consistent with adequate air traffic control service.

Figure 3.1

RELATIONSHIP OF TERMINAL AREA AVERAGE AIRCRAFT DELAY TO THE RATIO OF SERVICE DEMAND ÷ SERVICE CAPACITY



year in the year 2000 if system capacity remains constant 2/ The projected increases are manifestations of the above described relationship between average aircraft delay and the ratio of aircraft demanding service to the maximum system capacity. At nine terminals, average aircraft delays could exceed 30 minutes by the year 2000 if no major changes occur in present airport capacities. Average delays of such duration could, at the extreme, result in the cancellation of flights. Table 3.1 provides additional information on projected average aircraft delays at terminals.

The UG3RD will reduce both aircraft and passenger delay from what otherwise might exist by increasing airport runway capacities. This will lower the ratio of the demand for service to the maximum physical capacity to provide service and as a result the average duration of delays will decrease.

The present cost-benefit analysis focuses on valuing the reduction of passenger and aircraft delays.

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2/ These estimates assume no major changes in the pattern of operations throughout the day from those that presently exist. Further, no aircraft diversions or cancellations were assumed. Effects of such changes are explored in Chapter 4. Estimates quoted here do assume, however, a greater proportion of wide-bodied aircraft in the fleet.

TABLE 3.1
ESTIMATED AVERAGE DELAYS
PER AIRCRAFT IN THE TERMINAL
AREA ASSUMING CONTINUATION OF
EXISTING RUNWAY CAPACITY
(MINUTES)

| TERMINAL | 1975 | 2000 |
|---|---|---|
| ATL | 3.76 | 17.78 |
| CLE | 3.26 | 9.52 |
| CVG | 1.06 | 37.95 |
| DAL | 1.59 | 5.20 |
| DFW | 1.28 | 5.68 |
| DTW | 1.09 | 2.03 |
| EWR | 2.58 | 36.79 |
| HNL | 5.33 | 2.73 |
| IAH | 0.85 | 7.97 |
| IND | 1.35 | 65.09 |
| LAS | 1.56 | 10.11 |
| LAX | 2.15 | 5.67 |
| MCI | 0.79 | 7.82 |
| MEM | 0.93 | 5.06 |
| MIA | 1.74 | 5.15 |
| MSP | 1.06 | 35.98 |
| MSY | 1.19 | 50.39 |
| PHL | 4.56 | 77.17 |
| PHX | 2.80 | 12.74 |
| PIT | 1.72 | 9.45 |
| SEA | 1.24 | 8.39 |
| STL | 4.99 | 116.58 |
| TPA | 0.68 | 9.91 |
| BOS | 2.66 | 24.96 |
| DCA | 4.78 | 5.19 |
| DEN | 5.75 | 14.99 |
| JFK | 6.48 | 134.07 |
| LGA | 6.32 | 25.12 |
| ORD | 8.65 | 23.88 |
| SFO | 5.82 | 112.95 |

The concept that benefits are associated with reductions in passenger delay can be rationalized by observing that in many cases, passengers do not derive satisfaction from the act of travel per se, but instead they derive satisfaction or value from the change in physical location. For this group, time expended in travel is time lost on other activities--work or leisure. The lost time has value (see for instance [19]) and one may use an estimate of the value of passenger time saved as a benefit of the system [23 and 98].

Costs experienced by air carriers in providing transportation service are a function, among other things, of the time and distance involved. Aircraft delays due to congestion increase transit times and distances, thereby increasing trip costs. Reduced delays and aircraft operating costs resulting from improvements in system capacity are benefits which may manifest themselves through some combination of higher air carrier profits or reduced passenger fares.

The present cost-benefit analysis does not include benefit values associated with the provision of additional capacity per se. Additional capacity per se can be valued, however, if one is willing to assume that air transportation service will be denied in the absence of additional capacity. 3/ Limitation of the total number of aircraft operations below present forecasts in order to maintain reasonable levels of aircraft delay is considered in the analysis of complementary policy strategies to the UG3RD (see Chapter 4). These analyses indicate that even if it becomes necessary to limit aircraft operations in order to reduce delay, it would still be possible to service all air passengers. Thus, the value attributed to increased capacity and reduced delay achieved by the UG3RD is limited in the present analysis to the sum of reduced passenger and aircraft delays without consideration of flight cancellations.

3.1.1.2 Reduced Costs of Delay

The cost of air traffic delay is partially dependent on the stage of a trip at which delay is encountered. Delays occurring on the ground before an aircraft starts its engines are less expensive than delays encountered on the ground or in the air when the engines are in operation. The cost differential is primarily attributable to the cost of fuel required for engine operation.

3/ See discussions of the concept of consumers' surplus given in [42 and 57].

It is possible to reduce the cost of some air traffic delays without reducing the length of delay. This may be accomplished by shifting airborne or ground delays after engine start-up to delays on the ground before engine ignition. The enroute traffic management features of UG3RD automation and flow control are designed to accomplish this end. Information on air traffic conditions and delay will be analyzed and used to determine optimum routing of aircraft and situations when it may be desirable to delay departing aircraft on the ground rather than in the air enroute to their destination.

Technical evaluations of the ability of flow control to shift delays to holds on the ground with engines off were not available when the present study was completed. Thus, only illustrative savings calculations could be performed. These are described in Appendix C.

3.1.1.3 Increases in Controller Productivity

Air traffic control service is presently provided through the cooperative effort of men and equipment. One feature of potential UG3RD investment is the automation of certain traffic control functions which are now performed manually. In its most elementary form, the automation program of the UG3RD ATC system may reduce controller labor involved in the dissemination of flight data essential to the control process. Advanced phases of potential automation, coupled with other UG3RD elements (DABS and IPC), will use computers to interpret air traffic data, predict potential traffic conflicts, and generate and transmit control messages to aircraft. These functions are now performed manually by controllers. A goal of UG3RD automation is to increase the amount of traffic which can be handled by controllers while maintaining or improving air safety. Successful implementation of the UG3RD ATC system may, therefore, reduce future controller staff requirements from levels that would be needed using today's traffic control technology.

Controller labor costs constitute a large fraction of the Federal Aviation Administration budget. If the UG3RD reduces the future amount of direct labor required to provide service from presently projected levels, the associated savings of wages and employee benefit costs may be considered a benefit. In the present study, these savings are termed "productivity benefits." They are aggregated with the values of other potential benefits and compared to UG3RD costs to determine the desirability of various alternative UG3RD investments.

#### 3.1.1.4 Improvements in Aviation Safety

For each aviation accident that occurs, costs are incurred. There is damage to the aircraft and other real property. Passengers, crew, and bystanders may be injured or killed. Hospital costs are associated with the treatment of injuries. Time away from vocational activity due to accidents results in wage losses. In the case of fatalities or disabling injuries, there is permanent loss of income and contributions to the economy. Also, there are frequently legal costs and indemnification awards for liability.

The alternative UG3RD configurations analyzed by the present study incorporate certain performance features likely to reduce the number of aviation accidents and fatalities. Midair collisions may be prevented due to the combined effects of automated conflict prediction and resolution in the terminal area and intermittent positive control of aircraft. Collisions of controlled aircraft with the terrain may be reduced due to ground proximity warnings issued by UG3RD automation features. Potential reductions in aviation accidents, injuries, and fatalities resulting from the UG3RD constitute a quantifiable benefit of the system.

### 3.1.2 Costs

Installation of the alternative UG3RD ATC configurations will result in additional costs to the FAA and direct users. For the FAA, the additional costs will consist of engineering and development outlays, facility and equipment expenditures, and operation and maintenance costs. To the extent that operation costs are reduced by means of increased controller productivity, the cost reduction is treated as a benefit (see discussion above). Direct users will incur increased equipment costs as a result of required UG3RD avionics purchases and installations. Also, the avionics maintenance cost of users will probably rise. As stated earlier, implementation of the UG3RD will reduce delay and thereby reduce aircraft operating costs. These reductions in operating cost are to be treated as a benefit (see discussion above).

## 3.2 Estimation Methodology

In general, the annual benefits and costs of the UG3RD system were estimated by valuing differences between characteristics of present ATC facilities and procedures and the characteristics of the

UG3RD ATC system. For each year during the period 1976 through 2000 (the estimated life span of the UG3RD), differences between airport capacity, aircraft and passenger delay, air traffic control and other air transportation inputs, aviation safety, environmental conditions, and energy consumption were estimated. These differences were valued to obtain marginal costs and benefits of UG3RD ATC improvements. Annual values were then discounted using procedures specified by the Office of Management and Budget [50] and aggregated to estimate UG3RD costs and benefits.

The same general procedure for calculating benefits and costs was followed for each of the five alternative configurations of the UG3RD listed in Table 2.1. Limited discussions of procedures used to estimate individual types of benefits and costs are provided below. Additional detail is documented in separately published working papers [56,60,65,94,95, and 96].

In assessing benefits and costs it was assumed (based on a review of present technical development plans [97 and 64]) that Configuration 1 would not attain full operational capability until 1985 and the remaining configurations would not be fully operable until 1990. Facility and equipment expenditures were timed to lead operational dates by appropriate minimum implementation periods.

### 3.2.1 Estimation of Delay Reduction Benefits

The value of delay reduction (1975 dollars) attributable to the UG3RD was estimated in a multistep procedure. First, the MITRE Corporation estimated the runway capacity (in terms of hourly acceptance rates) of the largest 30 terminals with and without various UG3RD improvements at five year intervals. Capacities were estimated using a single runway throughput type of procedure which is described, along with calculation results, in the working paper Estimation of UG3RD Capacity Impacts [65]. Using these capacity estimates and official FAA forecasts of terminal area operations and enplanements from UG3RD Baseline and Implementation Scenario [96], Battelle Columbus Laboratories next calculated estimates of annual and average aircraft delay in minutes with and without the UG3RD at five-year intervals. Delay estimates were obtained from application of a deterministic, steady state runway queuing model. The actual delay estimation is described in Estimation of UG3RD Delay Reduction [56] and the basic queuing model used by Battelle is described in Airport Demand/Capacity Analysis Methods [4].

Multiplication of average annual delay per aircraft by the forecast number of passenger enplanements yielded an annual estimate of total passenger delay in minutes. See Tables 3.2 and 3.3 for aircraft and passenger results for 1975 and 2000. Among the five configurations analyzed, there are only two levels of increased terminal area capacity. An initial capacity increase is achieved by Configuration 1. Further improvements are obtained with Configuration 2, but the technical features of Configurations 3 through 5 do not provide increases in terminal runway capacity beyond this level.

Both annual aircraft delay and passenger delay minutes were converted to hours of delay and then multiplied by hourly unit costs to determine the cost of delay under each scenario. Aircraft unit costs were developed by the Transportation Systems Center for individual terminals based on future mixes of aircraft types (see Estimation of UG3RD Costs [95]). Cost data by type of aircraft were taken from Aircraft Operating Cost and Performance Report, FY 1974, Civil Aeronautics Board [10]. Passenger delay is valued at $12.50 per hour--the current DOT-FAA standard for air travel [95].

Finally, the difference in delay with and without the UG3RD improvements was calculated for five-year intervals over the time span 1976 through 2000. Values in intervening years were established by linear interpolation. 4/

4/ While the relationship between the level of annual delay and time is nonlinear, errors resulting from the linear interpolation of delay estimates are believed within the range of the estimation error associated with the delay estimation procedure.

TABLE 3.2
ESTIMATED ANNUAL AIRCRAFT DELAY
(millions of minutes)

| Year | 1975 | 2000 | | |
|---|---|---|---|---|
| Terminal | Current Capacity | Current Capacity | UG3RD Configuration 1 | UG3RD Configurations 2 thru 5 |
| ATL | 1.89 | 13.24 | 9.66 | 3.86 |
| CLE | 0.84 | 3.09 | 2.35 | 1.41 |
| CVG | 0.16 | 14.61 | 6.43 | 3.90 |
| DAL | 0.41 | 1.95 | 1.61 | 1.07 |
| DFW | 0.44 | 3.45 | 3.03 | 2.34 |
| DTW | 0.28 | 0.75 | 0.66 | 0.47 |
| EWR | 0.57 | 15.08 | 10.63 | 4.94 |
| HNL | 1.63 | 1.12 | 1.01 | 0.81 |
| IAH | 0.16 | 3.59 | 2.96 | 1.75 |
| IND | 0.27 | 33.19 | 24.73 | 11.13 |
| LAS | 0.40 | 4.55 | 3.71 | 1.94 |
| LAX | 1.00 | 3.40 | 2.60 | 1.25 |
| MCI | 0.14 | 3.52 | 2.93 | 2.34 |
| MEM | 0.27 | 3.04 | 2.62 | 2.06 |
| MIA | 0.57 | 2.57 | 2.27 | 1.77 |
| MSP | 0.41 | 19.42 | 13.75 | 6.33 |
| MSY | 0.19 | 21.16 | 15.16 | 5.77 |
| PHY | 1.44 | 38.59 | 27.49 | 8.32 |
| PHX | 1.22 | 8.41 | 7.06 | 4.81 |
| PIT | 0.50 | 4.72 | 4.05 | 2.83 |
| SEA | 0.19 | 2.52 | 1.85 | 0.98 |
| STL | 1.67 | 62.95 | 46.05 | 16.38 |
| TPA | 0.13 | 5.95 | 4.95 | 3.25 |
| BOS | 0.79 | 10.48 | 8.05 | 3.85 |
| DCA | 1.56 | 1.56 | 1.35 | 1.02 |
| DEN | 2.18 | 7.19 | 5.68 | 2.29 |
| JFK | 2.33 | 80.44 | 57.04 | 14.91 |
| LGA | 2.14 | 10.05 | 7.16 | 3.89 |
| ORD | 5.89 | 18.17 | 12.08 | 5.32 |
| SFO | 1.97 | 62.12 | 48.71 | 18.22 |
| 30 Airport Totals | 31.64 | 460.88 | 337.64 | 139.21 |

Source: Estimation of UG3RD Delay Reduction [56].

TABLE 3.3

Estimated Annual Passenger Delay
(millions of minutes)

| Year | 1975 | 2000 | | |
|---|---|---|---|---|
| Terminal | Current Capacity | Current Capacity | UG3RD – Configuration 1 | UG3RD – Configurations 2 thru 5 |
| ATL | 89.06 | 1231.52 | 898.10 | 358.69 |
| CLE | 19.69 | 168.15 | 127.77 | 76.78 |
| CVG | 3.08 | 318.82 | 140.39 | 85.06 |
| DAL | 10.90 | 29.06 | 24.03 | 15.89 |
| DFW | 9.86 | 166.83 | 146.55 | 113.26 |
| DTW | 9.11 | 50.26 | 43.89 | 31.15 |
| EWR | 19.16 | 822.58 | 579.94 | 269.53 |
| HNL | 48.33 | 75.14 | 67.65 | 54.22 |
| IAH | 4.68 | 136.76 | 112.75 | 66.82 |
| IND | 3.65 | 579.91 | 431.97 | 194.38 |
| LAS | 8.15 | 156.32 | 127.34 | 66.86 |
| LAX | 52.00 | 241.48 | 184.32 | 88.57 |
| MCI | 3.13 | 153.43 | 127.79 | 101.89 |
| MEM | 3.40 | 54.06 | 46.61 | 36.60 |
| MIA | 20.01 | 184.48 | 162.38 | 126.87 |
| MSP | 10.24 | 653.08 | 462.51 | 212.71 |
| MSY | 5.62 | 720.07 | 515.96 | 196.31 |
| PHI | 36.97 | 2074.37 | 1477.93 | 447.27 |
| PHX | 11.26 | 152.99 | 128.43 | 87.51 |
| PIT | 13.38 | 228.38 | 195.90 | 136.99 |
| SEA | 6.47 | 131.18 | 96.95 | 50.94 |
| STL | 36.83 | 3717.58 | 2719.36 | 967.52 |
| TPA | 3.33 | 152.55 | 127.01 | 83.37 |
| BOS | 27.47 | 829.31 | 636.80 | 304.22 |
| DCA | 57.07 | 164.15 | 141.94 | 108.02 |
| DEN | 60.18 | 467.54 | 369.00 | 148.56 |
| JFK | 139.91 | 6136.34 | 4351.49 | 1137.08 |
| LGA | 98.69 | 917.66 | 653.88 | 355.37 |
| ORD | 283.49 | 1829.84 | 1216.23 | 535.74 |
| SFO | 92.54 | 5229.69 | 4100.71 | 1533.94 |
| 30 Airport Totals | 1,187.56 | 27,773.53 | 20,415.58 | 7,991.82 |

Source: Estimation of UG3RD Delay Reduction [56].

### 3.2.2 Estimation of Controller Productivity Benefits

Potential savings obtained by means of reduced FAA controller personnel costs are regarded as a benefit of the UG3RD ATC system. Based on traffic forecasts provided in UG3RD Baseline and Implementation Scenario [96] and present staffing standards, controller staff at enroute centers and the 30 largest terminals (see Table 2.2) is estimated [22] to grow from 11,081 in 1974 to 25,587 by 2000. Implicit in this estimate is an assumption that in the future controllers will have the same amount of support equipment per controller as at present. 5/ If the total level of capital supporting air traffic control remains at its present level, then the future number of required controllers would probably be much larger than projected using present staffing standards. For example, controllers required at enroute centers are presently estimated to grow from 9,261 to 22,042 by 1990 according to present standards. Assuming no growth in total air traffic control equipment, however, enroute controller requirements might reach 27,210, or 5,168 controllers more than estimated under present staffing standards by 1990. 6/

One of the potential advantages of advanced automation is that it may change the capability of controllers to handle traffic. It is anticipated that the UG3RD will increase controller productivity by increasing the ratio of aircraft operations per controller from present levels. Thus, the UG3RD investment may lower staffing requirements for the period 1976 through 2000 from those required under a continuation of present technology.

Potential increase in controller productivity associated with various ATC improvements (increased ratios of operations per controller while maintaining or improving the quality of service) have been estimated by Stanford Research Institute (SRI) [17] and Metis Corporation [40]. Alternatively, estimates of future controller productivity with and without UG3RD investment may be obtained from ATC system production functions developed by Administrative Sciences Corporation

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5/ Present standards are based on actual observations of controller performance given a certain amount of supporting equipment.

6/ This estimate is calculated using an economic production function for air traffic control activity at enroute centers [2] and forecasts of aviation activity [96]. The function is $Q = .806\, L^{.681} K^{.328}$ where Q = aircraft handled, K = value of enroute capital equipment, and L = number of controllers.

and Noah Associates [2]. For purposes of the present cost-benefit analysis, estimated controller cost savings reported are those based on the SRI-Metis technique; the econometric results are sometimes noted in the following analysis as supporting evidence.

Under the SRI-Metis approach, controller staff requirements were estimated separately for enroute centers and for TRACONS and tower cabs at the 30 largest air carrier terminals. Staffing estimates were constructed first assuming no change from present technology and then assuming implementation of the various alternative UG3RD configurations. Specific estimates of staff requirements were prepared at five-year intervals over the time span 1976 through 2000. A summary of results is given in Table 3.4.

To develop these estimates, the number of controllers required at a sample facility was first determined from an analysis of specific job functions. These sample facility results were then expanded to provide estimates of required staff at all centers and subject TRACONS and towers (see Table 2.2) for the study period. Further details of this phase of estimation are given in Estimation of UG3RD Productivity Impacts [94].

Next, the five-year interval requirements were interpolated to obtain annual staff requirements. Finally, the manpower differentials with and without various UG3RD configurations were calculated and valued at a 1975 average wage of $24,795 [37] to estimate potential productivity benefits. Results of this procedure are presented and analyzed in the next major section of this Chapter, 3.3 Presentation of Results.

### 3.2.3 Estimation of Airway Safety Benefits

An analysis of the value of safety benefits obtainable from various UG3RD ATC investment alternatives was performed by The MITRE Corporation [60] and is based on the central assumption that the frequency of aviation accidents per operation observed in the past will be repeated unless identifiable steps are undertaken to eliminate specific classes of accidents. Recent accident data (1964 through 1972) on midair collisions and controlled collisions with the terrain were examined to determine what types of accidents might be prevented by the UG3RD system configurations. From this evaluation "preventable accident" rates were calculated and used to forecast, at five-year intervals, the number of future accidents that would be prevented by planned extensions of today's ATC system (such as TCA's, extended radar coverage, and

TABLE 3.4
ESTIMATED CONTROLLER
STAFF REQUIREMENTS
IN THE YEAR 2000 1/
(number of controllers)

| Equipment Assumption \ Facility | Enroute Centers | 30 Major TRACONS and Towers |
|---|---|---|
| present system | 22,042 2/ | 3,545 |
| UG3RD Configuration 1 | 14,214 | 2,924 |
| UG3RD Configurations 2 and 4 | 14, 107 | 2,031 |
| UG3RD Configurations 3 and 5 | 13,900 | 2,031 |

Source: Estimation of UG3RD Productivity Impacts [94].

1/ The relative relationship of staffing requirements given for the year 2000 will vary in early years depending on how the individual technologies respond to variations in traffic workload.

2/ A ceiling level of 22,042 required controllers will be reached in 1987. While traffic levels after that date will require additional controllers, additional traffic could not be accomodated without unreasonably long delays. Thus, no further increases in controller staff are estimated after reaching a level of intolerable aircraft delay.

conflict alert) and also those that would conceivably be prevented by features of the UG3RD configurations. Detail was separately provided for air carriers, air taxis, and general aviation on midair collisions and controlled collisions with the terrain. Further, preventable accidents associated with each equipment option were identified as to whether the prevention capability was redundant of ATC improvements already instituted or programmed for near term introduction. The five-year interval estimates were then interpolated to obtain annual estimates. A summary of these results is given in Table 3.5.

The value of UG3RD safety improvements was estimated as the sum of the value of accidents prevented exclusively by UG3RD features plus 5 percent of the value of accidents where UG3RD features provided a secondary or backup prevention system. Inclusion of this latter value is justified on the grounds that no safety system is 100 percent effective. It was therefore assumed that the primary prevention system would be effective 95 percent of the time and the secondary system would prevent the remaining 5 percent of the accidents in the subject accident category. The values of accidents prevented were calculated by multiplying the number of accidents prevented by unit accident costs established by the Transportation System Center [71]. Results from this final phase of estimates are presented in Section 3.3 of this chapter. A key methodological point is that the safety estimates are based on an exact duplication of past safety history and must be interpreted in that light. Actual future occurrences may vary greatly from the expected value estimates.

### 3.2.4 Estimation of Energy and Pollution Reduction

By reducing aircraft delays, UG3RD may produce both significant fuel savings and reduce the amount of air pollution associated with aircraft engine emissions. Estimates of fuel savings and pollution reduction--carbon monoxide, hydrocarbons and nitrogen oxide--have been prepared and are given in Section 3.3. The estimates are based on an average fuel saving or pollution rate per minute for each of the 30 terminal areas studied. These coefficients were calculated by weighting individual aircraft fuel and pollution rates [1] by the fleet mix forecase for each terminal. Total fuel saving or pollution reduction is the product of annual aircraft delay savings (in minutes) at various terminals and relevant fuel consumption and pollution rates.

TABLE 3.5
**ESTIMATED ACCIDENT PREVENTION**
(1975–2000)

| Accidents Prevented by Type / Equipment Assumption | Planned Extension of Present System (TCA/ERS, GPWS, Conflict Alert) | UG3RD Configuration 1, 2, and 3 | | UG3RD Configuration 4 | | UG3RD Configuration 5 | |
|---|---|---|---|---|---|---|---|
| MIDAIR COLLISIONS | | | | | | | |
| AIR CARRIER | 41 | 41 | (16) | 43 | (28) | 48 | (34) |
| AIR TAXI | 39 | 39 | (19) | 47 | (26) | 59 | (26) |
| GENERAL AVIATION | 842 | 842 | (94) | 1128 | (249) | 1388 | (311) |
| SUBTOTAL | 922 | 922 | (129) | 1218 | (303) | 1495 | (371) |
| CONTROLLED WITH TERRAIN | | | | | | | |
| AIR CARRIER | 132 | 132 | (41) | 132 | (49) | 134 | (56) |
| AIR TAXI | 99 | 99 | (37) | 149 | (59) | 225 | (98) |
| GENERAL AVIATION | 244 | 244 | (28) | 557 | (150) | 1061 | (268) |
| SUBTOTAL | 475 | 475 | (106) | 838 | (258) | 1420 | (422) |
| TOTAL | 1397 | 1397 | (235) | 2056 | (561) | 2915 | (793) |

( ) = Baseline Prevented Accidents also prevented by elements of the UG3RD configuration

### 3.2.5 Cost Estimates

Annual estimates of the cost of proposed UG3RD ATC system improvements to both the FAA and users have been prepared by the Transportation Systems Center [71]. Detail was provided by individual UG3RD component on engineering and development costs, facility and equipment expenditures and operations and maintenance expenditures (except controller and aircraft operating cost differentials where anticipated savings are construed as UG3RD system benefits). System cost estimates by year represent a synthesis of estimates compiled from (1) present FAA program cost estimates given in UG3RD Baseline and Implementation Scenario [96], (2) data taken from individual component cost benefit analyses [16,39,40,68 and 73] and other special studies on avionics costs, maintenance costs, and avionics equipment rates [35].

User costs of the UG3RD depend not only on the prices of avionics equipment, but also on the quality of equipment purchased by user and the extent to which the aircraft fleet is outfitted. Given uncertainty about the future equippage level of the fleet and the quality of avionics which will be installed, a range estimate of user costs was established for the DABS/IPC component. The lower bound assumes a predominance of standard and medium quality avionics in the fleet, the upper bound includes a larger proportion of airline quality avionics.

Assumptions on the dates of UG3RD installation and concurrent FAA F&E expenses are given in Table 3.6. The installation periods reflect the minimum time needed to meet operational dates adopted for the study. Operational dates, also given in Table 3.6, reflect both an assessment of the current rate of progress in technical development [97 and 64] and system financial planning considerations [96].

TABLE 3.6
ASSUMED DATES OF
UG3RD Operational CAPABILITY
AND ASSOCIATED INSTALLATION
DATES

| UG3RD Configuration | Date of Full Operational Capability | Facility Equipment Expenditure Period |
|---|---|---|
| 1 | 1985 | 1976-1982 |
| 2 | 1990 | 1976-1990 |
| 3 | 1990 | 1976-1990 |
| 4 | 1990 | 1976-1990 |
| 5 | 1990 | 1976-1990 |

### 3.3 Cost-Benefit Results

Annual estimates of benefits and costs associated with several versions of the UG3RD ATC system were estimated as described above (see Appendix Tables A.1 through A.5). These estimates were then converted to present values by application of a 10 percent discount rate (see Appendix Tables A.6 through A.10). An analysis of costs and benefit estimates follows.

#### 3.3.1 Overall Appraisal of Alternative Configurations of the UG3RD ATC System

For each of the configurations evaluated, the estimated benefits of the UG3RD system to users and the FAA significantly exceed costs. Table 3.7 provides a summary of the present value of benefits and costs, net benefit, and benefit-to-cost ratios for each UG3RD configuration. Using the upper bound of UG3RD cost estimates (large proportion of airline quality avionics), ratios of benefits-to-costs for the five configurations range from a high of 19:1 for Configuration 1 to 10:1 for Configuration 5. If the future general aviation fleet is assumed to contain less airline quality DABS/IPC avionics and equally more standard and medium quality sets, the benefit-to-cost ratios range from 22:1 for Configuration 2 to 17:1 for Configuration 5. As indicated in Figure 3.2, the greatest safety benefits are achieved in Configurations 4 and 5 where IPC acts to reduce midair collisions and collisions with the terrain.

The annual rate of benefits for each configuration generally becomes significant only after 1980, the period when major components are being installed and become at least partially operational (see Figure 3.3). Present values of annual benefits generally tend to increase significantly from their initial levels until they reach a plateau determined jointly by the operational capability inherent in the equipment and usage of the airway system. For example, annual total benefits for Configuration 1 become significant in 1981 at a present value of $111 million and then grow through 1992 when they reach a present value of $412 million per annum. Similarly, the annual present value of benefits for Configuration 5 becomes significant in 1981 at a rate of $179 million and grows to $1,032 million per year by 1992. These general trends are illustrated in Figure 3.3. Estimates of the present annual value of costs are characterized by high initial rates of expenditure during the design and implementation phase. The present value of costs declines

TABLE 3.7

PRESENT VALUE OF BENEFITS AND COSTS OF
ALTERNATIVE UG3RD ATC SYSTEMS 1976-2000
(millions of 1975 $)

| UG3RD Configuration | Benefits1/ | Costs2/ | Net Benefit | Benefit Cost Ratio |
|---|---|---|---|---|
| 1 | $ 7,367 | $ 391 | $6,976 | 19 |
| 2 | 16,494 | 738 - 1,170 | 15,323 - 15,755 | 14 - 22 |
| 3 | 16,603 | 797 - 1,229 | 15,374 - 15,806 | 14 - 21 |
| 4 | 16,559 | 895 - 1,333 | 15,226 - 15,664 | 12 - 19 |
| 5 | 16,757 | 1,002 - 1,627 | 15,130 - 15,755 | 10 - 17 |

1/ Benefits exclude reduced costs of aircraft delay associated with flow control. See Appendix C.

2/ Cost ranges given for Configurations 2 through 5 reflect different assumptions regarding DABS/IPC equipment installed in aircraft fleet.

# FIGURE 3.2
# UG3RD COSTS AND BENEFITS

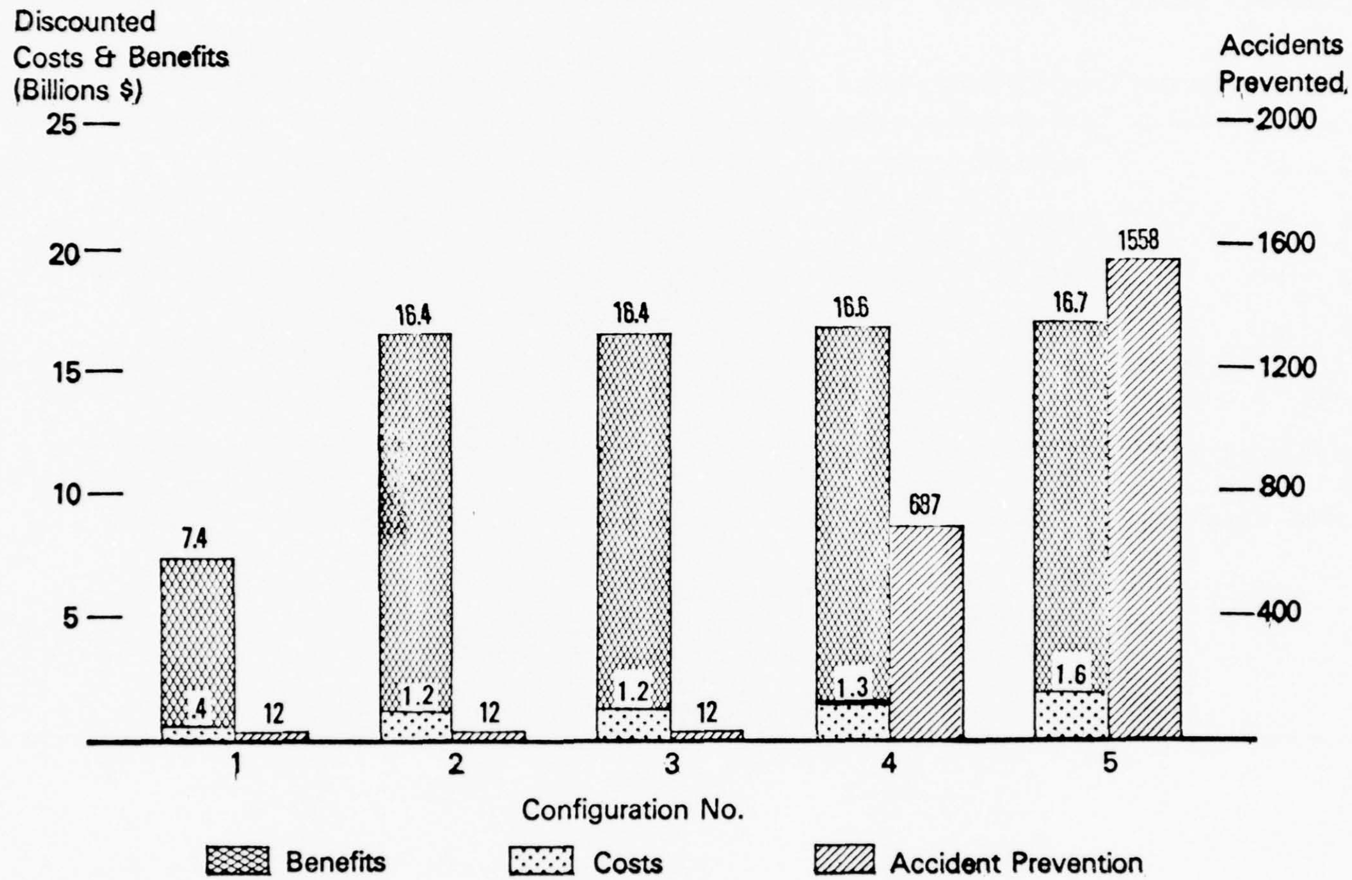
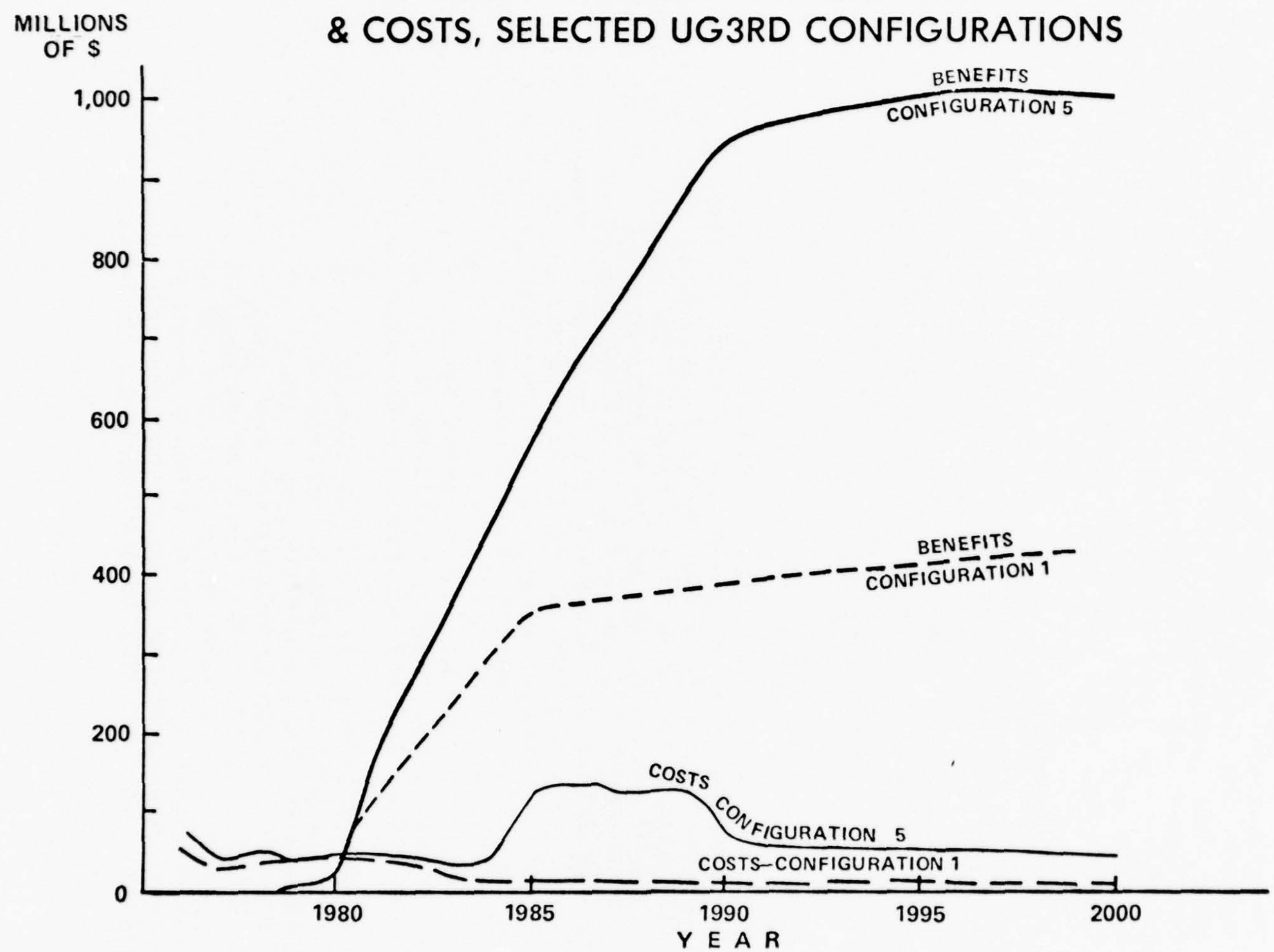


FIGURE 3.3

PRESENT VALUE OF ANNUAL BENEFITS
& COSTS, SELECTED UG3RD CONFIGURATIONS



substantially in later years due to the discounting process used in estimation, but also because total undiscounted annual expenditures are limited to normal replacement and maintenance activity during the latter portion of equipment life.

The cumulative present value of system benefits generally exceeds the cumulative present value of system costs by the year 1983 (see Figure 3.4). By 1983, each of the UG3RD configurations evaluated will provide sufficient benefits to cover the cost of the program. Significant benefit streams will start accruing as soon as programs can be made operational under the present rate of technical progress.

### 3.3.2 Benefits

The value of passenger delay and aircraft delay savings account for 84 percent or more of the total benefit associated with each configuration (see Table 3.8). FAA staff savings account for the remainder with the value of accident reduction limited to less than one percent of the total benefit except in the case of Configuration 5.

#### 3.3.2.1 Delay Reduction

Maximum delay savings due to reduction of the average delay encountered at terminals is attained with the implementation of Configuration 2 (automated WVAS, advanced automation, and DABS at 100 sites). The present discounted value of passenger and aircraft delay savings over the period 1976 through 2000 is \$6.4 and \$8.7 billion respectively for Configuration 2. Alternatively, savings obtainable from Configuration 1 (manual WVAS, basic automation) are \$2.7 billion for passenger delay and \$3.5 billion for aircraft delay savings. Neither the extension of DABS nor the addition of IPC provided by Configurations 3 through 5 is expected to further increase maximum physical capacity of the various terminals [64]. Hence, Configurations 3 through 5 provide the same level of delay savings as obtainable from Configuration 2.

Increases in airport physical capacity (along with associated delay reduction) attainable from various alternative UG3RD configurations are produced by features which influence aircraft separation standards and the level of control in bringing the aircraft to the final approach phase of landings. It is the WVAS, automation (metering and spacing) and improved surveillance (DABS) features which increase physical capacity; other aspects of the UG3RD do not significantly impact the ability of terminals to accommodate runway operations [64].

Figure 3.4
CUMULATIVE PRESENT VALUE OF BENEFITS
& COSTS, SELECTED UG3RD CONFIGURATIONS

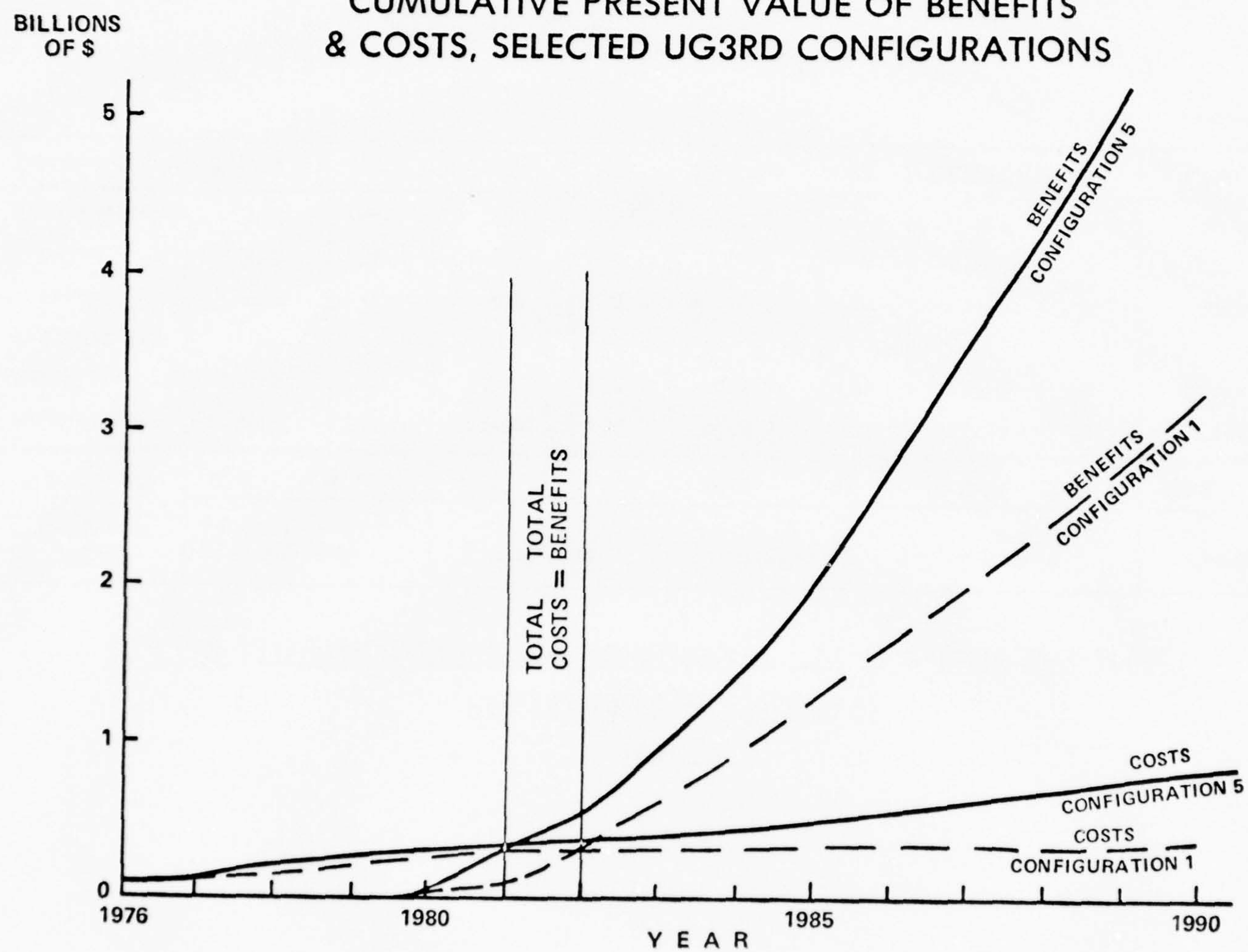


TABLE 3.8

## PRESENT VALUE — BENEFITS OF
## OF ALTERNATIVE UG3RD CONFIGURATIONS BY TYPE OF BENEFIT 1976-2000

| UG3RD Configuration | Configuration 1 | | Configuration 2 | | Configuration 3 | | Configuration 4 | | Configuration 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Type of Benefit | $\$(10)^6$ | % Total | $\$(10)^6$ | % Total | $\$(10)^6$ | % Total | $\$(10)^6$ | % Total | $\$(10)^6$ | % Total |
| Passenger Delay | $2,666.5 | 36 | $6,463.4 | 39 | $6,463.4 | 39 | $6,463.4 | 39 | $6,463.4 | 38 |
| Aircraft Delay | 3,531.8 | 48 | 8,741.6 | 53 | 8,741.6 | 53 | 8,741.6 | 53 | 8,741.6 | 52 |
| FAA Staff Savings | | | | | | | | | | |
| Terminal | 57.9 | 1 | 109.3 | 1 | 109.3 | 1 | 109.3 | 1 | 109.3 | 1 |
| Enroute | 1,097.3 | 15 | 1,165.8 | 7 | 1,275.7 | 7 | 1,165.8 | 7 | 1,275.7 | 8 |
| Accident Reduction | 13.3 | - - | 13.3 | - - | 13.3 | - - | 78.6 | - - | 166.9 | 1 |
| • Total Benefits | $7,366.9 | 100 | $16,493.4 | 100 | $16,603.3 | 100 | $16,558.7 | 100 | $16,756.9 | 100 |

Airports with a predominant dual-lane runway structure and where a large share of total operations involves heavy aircraft will accrue the greatest benefits from implementation of the UG3RD. As compared to today's system, it was concluded [65] that greater capacity benefits will result under IFR conditions than under VFR conditions. The IFR capacity should approach the VFR capacity as elements of the UG3RD system are implemented. Average runway throughput increases were 23 percent for VFR conditions and 39 percent for IFR conditions.

### 3.3.2.2 Controller Productivity

Potential cost savings attributable to reduced air traffic control manpower requirements range from \$1.1 billion, assuming Configuration 1, to \$1.4 billion assuming Configuration 5. These values reflect the total present value of controller staff savings for the period 1976 through 2000. Most of the savings result from reduced staff requirements at enroute centers which produce between \$1.1 to \$1.3 billion in lower costs. UG3RD installations at the 30 air traffic terminals produce between \$58 million and \$109 million in savings. A review of cost data given in Table 3.12 indicates that the productivity savings alone from Configuration 1, \$1.1 billion, should exceed the total present value of the cost of implementing the configuration, \$391 million, by a wide margin. For the Configurations 2 and 3, productivity benefits alone are about equal to the costs of implementation. Productivity benefits exceed the FAA costs of Configurations 4 and 5 and also exceed total costs assuming that the lower bound estimate of DABS/IPC user costs is the relevant scenario.

Alternative UG3RD configurations evaluated in this study provide two basic levels of productivity improvement. Configuration 1 creates savings as a result of the automation features of the UG3RD. Specific features increasing output per controller are automated data handling and metering and sequencing. Assuming creation of an adequate tabular data display for enroute and terminal control positions, the automated data handling features of UG3RD Configurations 1 through 5 would permit removal of flight strip printers and reductions in staff where a significant number of personnel are currently required to distribute flight strips. The reductions would be most dramatic at enroute centers, but would also occur at the larger terminal facilities. Some degree of workload reductions will also be realized from the basic metering

and sequencing feature of terminal area automation. Computerized metering and sequencing will reduce controller decision times necessary to mentally assess and determine aircraft sequence assignments and will also reduce aircraft conflicts along inbound flightpaths. These workload reductions are expected to justify staffing reductions [17]. Enroute metering and flow control will not significantly impact controller workload [17].

Automated conflict processing, control message generation, and automated control message transmission via DABS/IPC are features common to Configurations 2 through 5. These elements are expected to automate routine conflict avoidance tasks of controllers and should therefore increase controller handling capacities permitting more efficient manning strategies and reduced staffing requirements.

Productivity benefits reported above reflect anticipated savings due to changes in control technology--increases in the ratio of aircraft handled to the number of controllers. It is important to note, however, that even in the absence of significant shifts in technology, there will be a continuing need for capital equipment in support of air traffic control (both for replacement of worn out items and to meet the needs of increased levels of air traffic). It is estimated that in order to handle future air traffic in the year 2000 in the most cost efficient manner using today's control technology will require net new investments (excluding replacement requirements) of between \$874 million and \$1.3 billion for terminal control equipment and between \$558 million and \$1.1 billion enroute centers. 7/

Failure to provide this level of equipment could result in higher than necessary unit costs of air traffic control. In addition to potential improvements in technology, many UG3RD programs such as automation and DABS serve to increase the amount of control equipment performing present types of aircraft surveillance and control tasks. Thus, many UG3RD programs will provide equipment of the type needed to produce air traffic control service at the lowest possible cost even assuming no major technological breakthroughs.

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7/ These estimates were derived as least cost combinations of capital and controller labor for the year 2000. Least cost estimates were in turn calculated using economic production functions of existing enroute and terminal air traffic control processes [2], forecasts of aviation activity [96], and estimated unit costs of capital and labor.

### 3.3.2.3 Improvements in Aviation Safety

The discounted present value of safety benefits for the various alternative UG3RD configuration ranges between $13 million and $167 million (see Table 3.9). Configuration 5 provides the maximum safety benefit. Only Configurations 4 and 5 are anticipated to decrease significantly the number of civil aviation accidents and fatalities from levels that would otherwise exist. Configurations 1 through 3 provide enhancements to safety through the provision of redundant safety features. As stated in Section 3.2.3, the backup role provided by certain UG3RD features is important because optimistic assumptions about the effectiveness of primary safety systems now being installed will only be validated through actual system operations. The present value of accidents where the UG3RD can provide redundant prevention capability range between $259 and $396 million (see Table 3.9) for the period 1976 through 2000.

Configurations 1 through 3 provide redundant accident prevention capability by alerting controllers automatically when controlled aircraft (IFR aircraft) are in danger of collision with the ground. Configuration 5 will extend accident prevention to VFR aircraft as well as IFR aircraft equipped with cooperative avionics. Configuration 4 will do this on a geographically limited basis. These latter configurations will prevent approximately 60 percent more midair collisions and collisions with terrain as continuing with today's system. Also, Configuration 5 could conceivably prevent approximately one-third more fatalities than could a continuation of today's system [71].

### 3.3.2.4 Energy and Pollution Impacts

Implementation of various configurations of the UG3RD will reduce fuel consumption and air pollution (hydrocarbon, carbon monoxide, and nitrogen oxide emissions)--events consistent with national goals of energy conservation and an improved environment. Both of these benefits result from reductions in aircraft delay due to UG3RD increases in airport capacity. Reduced flight time saves fuel and reduces engine emissions. Table 3.10 presents data on the impact of the UG3RD on aircraft fuel consumption and air pollution over the period 1976 through 2000. Configuration 1 reduces fuel consumption and air pollution emissions by 24 percent from the levels associated with aircraft delays that would occur in the absence of the UG3RD. Configurations 2 through 5 produce a 64 percent reduction from levels associated with aircraft delay in the absence of the UG3RD.

TABLE 3.9

PRESENT VALUE OF UG3RD ACCIDENT PREVENTION CAPABILITIES 1976–2000

(Millions 1975 Dollars)

| UG3RD Configuration | Accidents Prevented by UG3RD | Accidents where UG3RD Provides Redundant Prevention Capability |
|---|---|---|
| 1 | $ 13 | $259 |
| 2 | $ 13 | $259 |
| 3 | $ 13 | $259 |
| 4 | $ 79 | $348 |
| 5 | $167 | $396 |

TABLE 3.10

ENERGY AND AIR POLLUTION
IMPACTS OF ALTERNATIVE UG3RD CONFIGURATIONS

| Impacted Item / Equipment Assumption | Quantity Attributable to Aircraft Delay | Reduction– UG3RD Configuration 1 | Reduction– UG3RD Configurations 2 – 5 |
|---|---|---|---|
| Hydrocarbon Emission ($10^6$pounds) | 7,566 | 1,842 | 4,611 |
| Carbon Monoxide Emission ($10^6$ pounds) | 14,307 | 3,536 | 8,976 |
| Nitrogen Oxide Emission ($10^6$ pounds) | 3.954 | 991 | 2,562 |
| Fuel Consumption ($10^6$ barrels) | 3,013 | 759 | 1,938 |

### 3.3.3 Costs

Only the FAA will experience marginal costs associated with UG3RD implementation if Configuration 1 is adopted (see Table 3.11). Under this combination of components, and in all other combinations evaluated, the present value of facility and equipment expenditures constitutes the largest portion of the present value of total FAA costs. This is as expected because maintenance expenses occurring toward the end of the study period are heavily discounted. Beginning with Configuration 2, user costs become a major element in the present value of total system cost ranging from 31 to 72 percent depending on the assumed quality and quantity of avionics installed in the fleet. It is the initial cost of purchasing the equipment and not the maintenance costs which will comprise the largest share of user costs.

Table 3.12 provides a break-down of the present value of costs, both for users and the FAA, by component.

### 3.3.4 Sensitivity of Benefit-Cost Results

Benefit estimates provided in Section 3.3.2 are sensitive to certain key assumptions regarding aviation activity during the period 1976 through 2000 and the performance of UG3RD components. First, the values of all envisioned benefits of the various UG3RD configurations--reduced aircraft and passenger delay, increased air traffic control productivity, and increased aviation safety are influenced by the anticipated number of annual aircraft operations, both at terminals and in the enroute system. Second, the values of reduced aircraft and passenger delay depend upon the mix of aircraft types (heavy, medium, light) operating at terminals. Third, the impact of UG3RD components, particularly WVAS, on increasing terminal capacity and reducing delays is a function of assumed technical effectiveness. The degree of sensitivity of various benefits estimates is discussed separately below.

Estimates of the sensitivity of the discounted value of aircraft and passenger delay to altered assumptions concerning terminal area activity level, mix of aircraft using the terminal, and the effectiveness of the Wake Vortex Avoidance System are provided for three selected terminal areas:

1. John F. Kennedy International Airport (JFK)
2. Logan Field, Boston (BOS)
3. New Orleans Moisant (MCI)

TABLE 3.11

PRESENT VALUE - COSTS OF ALTERNATIVE
UG3RD CONFIGURATION BY TYPE OF COST 1976-2000

| UG3RD Configuration<br>Type of Cost | Configuration 1<br>$\$(10)^6$ | Configuration 2<br>$\$(10)^6$ | Configuration 3<br>$\$(10)^6$ | Configuration 4<br>$\$(10)^6$ | Configuration 5<br>$\$(10)^6$ |
|---|---|---|---|---|---|
| FAA Costs | | | | | |
| Engineering & Development | $112.0 | $153.9 | $153.9 | $163.5 | $163.5 |
| Facilities & Equipment | 164.3 | 256.2 | 295.3 | 259.9 | 305.4 |
| Maintenance | 115.0 | 169.8 | 189.8 | 175.3 | 204.2 |
| User Costs | | | | | |
| Avionics | | | | | |
| High Quality Equip. Assump. | - | 396.7 | 396.7 | 495.2 | 600.6 |
| Std.-Med. Quality Equip. Assump. | - | 120.0 | 120.0 | 213.0 | 231.0 |
| Maintenance | | | | | |
| High Quality Equip. Assump. | - | 193.6 | 193.6 | 239.2 | 353.5 |
| Std.-Med. Quality Equip. Assump. | - | 39.0 | 39.0 | 84.0 | 98.0 |
| Total Costs | $391.4 | | | | |
| High Quality DABS/IPC Assump. | - | $1,170.2 | $1,229.3 | $1,333.2 | $1,627.4 |
| Std.-Med. Quality DABS/IPC Assump. | - | $ 738.7 | $ 797.8 | $ 895.6 | $1,002.1 |

TABLE 3.12

PRESENT VALUE - COSTS OF ALTERNATIVE
UG3RD CONFIGURATION BY COMPONENT 1976-2000

| UG3RD Configuration<br>Type of Cost | Configuration 1<br>$\$(10)^6$ | Configuration 2<br>$\$(10)^6$ | Configuration 3<br>$\$(10)^6$ | Configuration 4<br>$\$(10)^6$ | Configuration 5<br>$\$(10)^6$ |
|---|---|---|---|---|---|
| WVAS | 39.6 | 40.0 | 40.0 | 40.0 | 40.0 |
| Automation | 351.6 | 470.7 | 470.7 | 470.7 | 470.7 |
| DABS/IPC | | | | | |
| High Quality Equip. Assump. | - | 659.3 | 718.4 | 822.5 | 1,116.7 |
| Std.-Med. Quality Equip. Assump. | - | 228.0 | 287.1 | 384.9 | 491.4 |
| Total | $391.4 | | | | |
| High Quality DABS/IPC Assump. | - | $1,170.2 | $1,229.3 | $1,333.2 | $1,627.4 |
| Std.-Med. Quality DABS/IPC Assump. | - | $ 738.7 | $ 797.8 | $ 895.6 | $1,002.1 |

In presenting these data, the sole objective is to illustrate the sensitivity of terminal delay phenomena to deviations from the FAA's best estimate of aviation activity provided in Baseline and Implementation Scenario [96] and WVAS technical capability given in Estimation of UG3RD Capacity Impacts [65]. The resulting delay estimates should not be interpreted as an alternative forecast.

For illustrative purposes, it was first assumed that the rate of growth in aircraft operations at the three terminals was reduced to half of the rate projected in UG3RD Baseline and Implementation Scenario [96]. Second, it was assumed that a more uniform mix of aircraft, composed primarily of B-707 B-727, and DC-9 aircraft constituted the population of terminal users. In general, this assumption reduced the proportion of heavy aircraft (B-747, DC-10, L-1011, and A-300) projected in UG3RD Baseline and Implementation Scenario [96] by as much as 50 percent. Finally, the percentage of time when WVAS was assumed fully effective and minimum separation standards are in effect was increased between 10 and 40 percent (see Estimation of Delay Reduction [56] for further discussion). Impacts of these various assumptions are presented in Tables 3.13 and 3.14 for the discounted value of aircraft and passenger delay. The value of delay savings are extremely sensitive to assumptions on activity level. Reducing the rate of air carrier operation growth by 50 percent causes the total value of delay savings to fall between 60 and 90 percent for the twenty year period from the values of savings calculated for the "best estimate" projection of terminal activity. Reducing the proportion of heavy aircraft by up to 50 percent of the "best estimate" proportion reduces delay savings between 10 and 40 percent. Finally, increasing assumptions about WVAS effectiveness increases delay savings from 20 to 100 percent over the "best estimate" of functional capability.

Estimates of the number of accidents prevented by various UG3RD configurations (primary prevention system capability only) were also calculated assuming that aviation activity only grows by one-half of the presently projected rate. These estimates are given in Table 3.15 and are contrasted with the number of accidents prevented under the "best estimate" of aviation activity. Cutting the growth rate in half reduces the number of accidents prevented by up to 40 percent. Further discussion of the sensitivity of safety benefits to the assumed level of aviation activity are given in Estimation of UG3RD Safety Benefits [60].

TABLE 3.13

PRESENT VALUE OF AIRCRAFT DELAY FOR DIFFERING OPERATING ASSUMPTIONS—— SELECTED TERMINALS 1976-2000 (MILLIONS 1975 DOLLARS

| Assumption | MSY | | BOS | | JFK | |
|---|---|---|---|---|---|---|
| | Conf. 1 | Conf. 2-5 | Conf. 1 | Conf. 2-5 | Conf. 1 | Conf. 2-5 |
| "Best Estimate" | $65 | $150 | $75 | $180 | $979 | $2,519 |
| One-half operations growth rate | 11 | 23 | 29 | 66 | 263 | 734 |
| Lower proportion of heavy aircraft | N/A | N/A | 69 | 164 | 887 | 1,730 |
| Increased WVAS Effectiveness | 175 | 348 | 149 | 234 | 1,646 | 2,764 |

TABLE 3.14

PRESENT VALUE OF FASSENGER DELAY FOR DIFFERING
OPERATING ASSUMPTIONS--
SELECTED TERMINALS 1976-2000
(MILLIONS 1975 DOLLARS)

| Assumption | MSY | | BOS | | JFK | |
|---|---|---|---|---|---|---|
| | Conf. 1 | Conf.2-5 | Conf.1 | Conf. 2-5 | Conf.1 | Conf. 2-5 |
| " Best Estimate" | $43 | $91 | $63 | $161 | $615 | $1,719 |
| One-half Operations growth rate | 4 | 7 | 18 | 32 | 179 | 310 |
| Lower Proportion of heavy aircraft | 36 | 82 | 39 | 124 | 551 | 1,494 |
| Increased WVAS Effectiveness | 51 | 112 | 90 | N/A | 1,024 | N/A |

TABLE 3.15

ACCIDENTS PREVENTED BY UG3 RD CONFIGURATIONS FOR DIFFERING OPERATING ASSUMPTIONS 1975 – 2000

| UG3RD Configuration | Accidents Prevented–– Best Estimate of Aviation Activity | Accidents Prevented–– 1/2 Growth Rate Estimate of Aviation Activity |
|---|---|---|
| Configuration 1 – 3 | 1,397 | 904 |
| Configuration 4 | 2,056 | 1,257 |
| Configuration 5 | 2,915 | 1,717 |

Source: Tables 3 – 1 and C – 2, Estimation of UG3RD Safety Benefits [60].

## 4.0 Complementary Policy Strategies

In addition to technical features of the UG3RD, there are certain noncapital or relatively low capital program alternatives which might be introduced. The question has been raised whether or not these noncapital alternatives, or complementary policy strategies, could be implemented in a timely and cost effective manner. This chapter examines the potential benefits of selected complementary policy strategies, including: pricing and administrative options such as quotas and time variable airport landing fees; increased utilization of satellite or secondary airports in major metropolitan areas and Terminal Control Area (TCA) restrictions on general aviation terminal activity.

Complementary policy strategies range from those which are primarily administrative to those which are of a purely economic character. Strictly speaking, of course, some of these measures do not expand airport capacity in the physical sense of making possible more aircraft movements per unit of time. They can, however, postpone the need for expansion of airport facilities by rationing runway use.

One reason for the interest in certain complementary policy strategies is the potential relief they might offer to increasing levels of Federal expenditure in the airport system, as well as the argument that one of the options--peak-time landing fees--would lead to a more efficient allocation of scarce runway space.

The characteristics of airport demand provide additional motivation for investigating these alternatives. For example, the level of demand, as measured by the number of aircraft requesting use of a typical airfield during a specific hour, varies widely in the course of an average day. If demand were smoothed throughout the operating period, less delay would accrue for an equivalent level of traffic handled.

Second, the economic value that different users derive from airfield usage varies according to type of aircraft, time of day and locality, among other things. The point can be made that society would benefit if higher valued users were allowed priority access to scarce runway space.

Third, some airport users are severely constrained as to type of airport facilities they require. Larger commercial aircraft, for example, have more stringent requirements for runway length, strength of pavement, and electronic instrumentation for landing approach than do many categories of general aviation users. Facilities for certain of these latter users are less expensive to build and operate, both in economic and political terms.

The benefits of complementary policy strategies can be manifested in terms of reduced congestion and delay at primary air carrier airports in the large metropolitan areas. The following sections of this chapter examine the impact on air traffic congestion and airport delay of the following complementary policy strategies: pricing and administrative options, increased utilization of satellite airports, and TCA restrictions on general aviation.

## 4.1 Pricing and Administrative Options

### 4.1.1 Pricing Options

The basic concept of pricing alternatives is the use of higher charges on aircraft (and/or passengers) to control airport congestion during periods of high demand. Theoretically, users confronted with such a pricing schedule will redistribute their demand more uniformly throughout the day, with only the highest valued users receiving service during the peak-demand period.

While the theory of peak pricing as a tool to spread demand away from periods of congestion has received a great deal of attention in the economic and technical literature, the theory has been applied at only a few airports. However, there are at least two well documented examples in which airports have imposed peak-hour charges to alleviate congestion. One of these is at Heathrow Airport, where the British Airport Authority (BAA) in 1971 imposed a peak-period surcharge on aircraft operations in an attempt to alleviate congestion in the airport terminals and access roads.

The BAA has taken a pragmatic approach with their fee schedule, and initially implemented a relatively small surcharge to accustom airport users to the concept. BAA is modifying the pricing scheme gradually as conditions allow. Although data indicates the peak-period surcharge has shifted demand slightly, it has not resulted in any major redistribution of traffic. It is noted, however, that the Heathrow peak-time charge (approximately $100) is imposed upon air carriers, which, as a group, are less sensitive to changes in operating expenses than are other sectors of the aviation community. This may account for the negligible impact of peak charges at Heathrow.

Results of the peak-pricing experiment at New York City airports, the second of the two examples, are more pronounced. In 1968, in order to alleviate congestion and make more capacity available for air carrier operations, the Port Authority of New York imposed a $25 fee for all landings and take offs during peak hours by aircraft with less than 25 seats. The normal landing fee was $5. The impact of the surcharge was immediate. For the three major New York airports, Kennedy, LaGuardia, and Newark, general aviation activity during high-activity hours dropped over 30 percent from pre-surcharge levels, indicating that peak-time landing fees can result in significant redistribution of particular user demands (general aviation) at a given airport and time of day.

#### 4.1.2 Administrative Options

Administrative alternatives typically involve some form of fiat rationing to restrict air traffic access to congested airports. These restrictions may be applied selectively on specific categories of aviation; they may be in force only for certain periods of a day; and/or apply to some but not all runways of an airport. Banning of general aviation flights from an airport or from some part of an airport is an example of an administrative option. Establishment of a "quota" system is perhaps the most familiar of these alternatives.

Administrative alternatives are easy to describe and comprehend. Their first-order and short-term effects are also straightforward and predictable: as the number of flights at an airport is reduced (due to quota limits on the number of flights that can be scheduled or to a ban on specific types of operations) congestion at an airport also decreases. In fact, since the relationship between airport demand and airport delay is nonlinear, a carefully chosen limit on the number of operations at a severely congested airport may lead to a significant reduction in the cost of delays, with a less than proportionate decrease in the number of flights allowed.

This phenomenon is illustrated in Figure 4.1, for year 2000 air carrier forecasts at Chicago O'Hare (ORD). The two demand curves shown in this figure represent projected air carrier traffic levels before and after the imposition of hypothetical quotas on operations. As explained later in this chapter, these forecasts were developed for this analysis to test the impact of airport capacity constraints on air traffic delay. Figure 4.1 shows that a daily quota of 1875 aircraft movements represents a 15 percent reduction in the number of ORD operations which might otherwise be anticipated in the year 2000. Delay, however, is more than proportionately reduced 53 percent, from the pre quota level of over 44,000 minutes each day to less than 21,000 minutes. Furthermore, the forecast indicates that more extensive use of wide-body aircraft under quota conditions would provide for equivalent numbers of passengers carried in either case.

It is little wonder that quotas and other administrative measures have been (and continue to be) particularly attractive to the various responsible bodies as a means of dealing swiftly and effectively with airside congestion. In 1969, for example, the FAA imposed hourly quotas on the scheduling of operations at the three New York City airports, O'Hare International in Chicago and Washington National. These quotas have been generally credited for relieving traffic congestion at these airports. Developments since 1969 have made it possible to eliminate the quota at J. F. Kennedy and Newark. However, the system continues to be in effect at the other three airports.

### 4.1.3 Analytical Approach

In order to examine the impact of pricing and administrative alternatives on congestion and delay at the primary air carrier airports, an experiment with four operational scenarios or situations was designed, each scenario

## FIGURE 4.1
## IMPACT OF QUOTAS ON AIRPORT DELAY

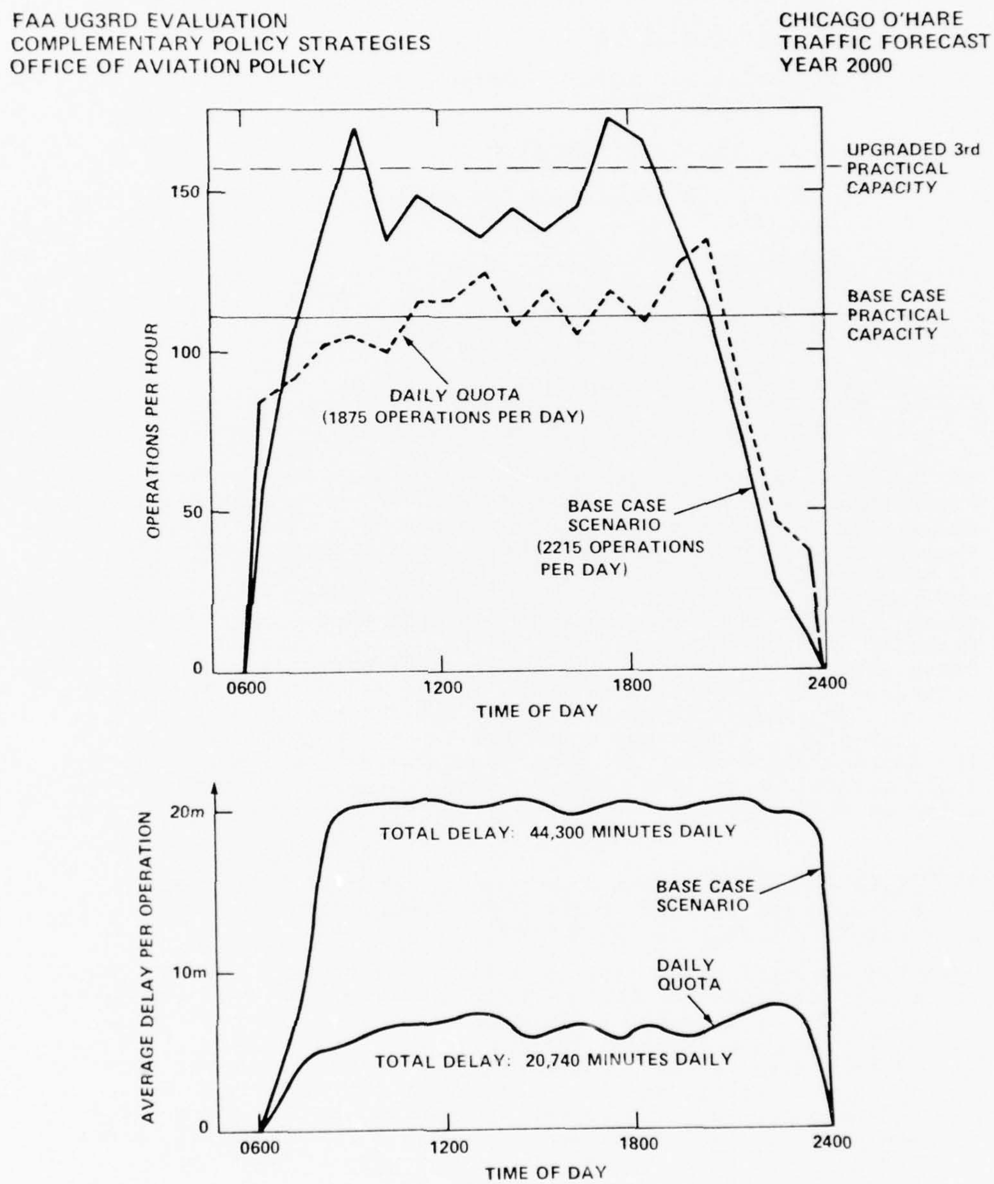




TABLE 4.4

representing a different development strategy for the national airport system. Two of the scenarios employed peak pricing and quotas to relieve congestion. The others did not. Airport system delays associated with each scenario were computed and compared. Any differences in delays observed were attributed to the unique features of each scenario. These scenarios include:

- Base Case Scenario

  Projected air traffic control system without UG3RD improvements

- Peak-Pricing Quota Scenario

  Pricing and administrative options, no UG3RD hardware

- UG3RD Scenario

  UG3RD airport improvements (Configuration 5 as defined in Table 2.1.)

- Peak Pricing, UG3RD Scenario

  UG3RD hardware plus peak pricing as necessary

The Base Case Scenario represents conventional airport configurations, without UG3RD improvements. 1/ No pricing or administrative options are employed. For this scenario an average of 20 percent of all airport traffic in each scenario is assumed to consist of general aviation, commuters, military, and nonscheduled operations. 2/ Given the projected airport capacities and levels of demand, delays at each airport were computed through the year 2000. Occasionally, certain airports experienced temporary situations where delays became untenably large, approaching an unlimited or infinite condition. To avoid this situation and bound the problem more realistically, flights are cancelled in each scenario whenever the average daily delay exceeds 20 minutes per operation. These situations are reflected in airport cancellation rates, shown in Figure 4.3 and discussed later in this section.

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1/ Airport capacities and improvement schedules under each scenario are defined in The MITRE Corporation memorandum W 43-127.7, July 31, 1975. [43]

2/ This assumption was made in order to facilitate the analysis. Latest figures show that general aviation, air taxi (commuter) and military aircraft traffic ranges from 16 percent of all operations (in Atlanta) to 65 percent (in Las Vegas). This traffic averages 20 percent of total at the top seven commercial airports, and for this reason the 20 percent estimate was chosen. The reader is referred to FAA Air Traffic Activity, CY 1974, DOT, FAA, March 1975, page 34, [81]. Also The National Aviation System: Challenges of the Decade Ahead 1977 1986, DOT, FAA, page 5, [92].

In the Peak Pricing and Quota Scenario, general aviation, military, commuter and nonscheduled traffic (20 percent of total) is assumed to be priced out of an airport whenever delays are encountered through the imposition of increased landing charges. 3/ This displaced traffic is not denied airport access altogether, however, for there still remains a variable amount of runway space available to them during VFR or off-peak conditions.

In the peak pricing and quota scenario, all airports incurring annual average delays of 6 minutes are subject to peak-time landing surcharges to redistribute air carrier activity. Where these actions are insufficient to maintain annual average delay at 6 minutes or less, quotas are imposed.

For the UG3RD Scenario, all airport capacities are increased by time phased hardware improvements of the UG3RD. 4/ No time variable airport pricing schemes are introduced. The fourth scenario, Peak Pricing, UG3RD Scenario, combines all the improved hardware and pricing features of the previous scenarios. No quotas are required in this last scenario due to the fact that airport demand is reduced through increased peak-time landing charges, while at the same time airport capacity is increased by UG3RD hardware improvements. The essential features of each of the four scenarios are summarized in Table 4.1.

To test the impact of these scenarios on airport system delay, a mathematical programming model was developed at the Massachusetts Institute of Technology (MIT) Flight Transportation Laboratory to represent the network of the 23 largest metropolitan air carrier centers or hubs. Simulating the planning and routing activities of the United States domestic airline industry, this fleet assignment model routed aircraft through the system of 243 city pairs or markets to provide

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3/ These users are generally more sensitive than air carriers to price increases. This is evidenced in a comparison of the Heathrow Airport and New York Port Authority peak-time pricing cases discussed earlier in this chapter. Increased landing fees at Heathrow have had very little impact on air carrier traffic distribution, whereas peak charges at New York had a noticeable effect on general aviation traffic. The reader is referred to the General Aviation Cost Impact Study, Vol. I, Battelle, Columbus, 1973, [5] for a discussion of price elasticities.

4/ The MITRE Corporation provided the schedule for these improvements. MITRE Corporation memorandum, W 43-127.7, July 31, 1975 [43].

## TABLE 4.1
## DESCRIPTION OF AIRPORT SYSTEM SCENARIOS

FAA UG3RD EVALUATION
COMPLEMENTARY POLICY STRATEGIES
OFFICE OF AVIATION POLICY

| | UG3RD IMPROVEMENTS | PEAK PRICING, QUOTAS |
|---|---|---|
| BASE CASE SCENARIO | | |
| PEAK PRICING, QUOTAS SCENARIO | | √ |
| UG3RD SCENARIO | √ | |
| PEAK PRICING AND UG3RD SCENARIO | √ | √ |



TABLE 4.5

either direct or multistop aircraft services to 25 major airports in accordance with a set of optimization criteria. For this analysis an airline strategy to maximize profits was adopted in order to provide a realistic air carrier environment. That is, it was assumed the airlines would behave rationally to maximize net revenues on the routes they were flying.

The fleet assignment model developed at MIT takes into account a wide choice of different routing possibilities for load building by combining several markets into non-stop flights, and the opportunities for stimulating demand by improving service levels. It is sensitive to practical limitations on load factors, aircraft availability, minimum or maximum service levels, airport capacity, and/or other constraints, such as the availability or price of fuel, which may be imposed externally. 5/

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5/ Two operating assumptions were made in the application of the fleet assignment model. The first assumption was that the degree of market competition extent today would prevail through the year 2000. In the past the Civil Aeronautics Board (CAB) has increased competition as market demand grew. The realities of energy availability, however, may change this trend. Should the CAB continue to allow more airlines to actively enter growing markets under noncollusive scheduling conditions, air traffic levels, and concomitantly, terminal delays will likely increase beyond the levels shown in this analysis.

The second assumption made was that markets external to the 23 city network modeled would grow at the same rate as the intra network markets. That is, the precentage of airport traffic serving external markets will remain constant through the year 2000. This is a conservative assumption made in the absence of more definitive information. At present, these external markets account for almost 50 percent of all commercial activity at the primary large hub airports. If these external markets grow faster than higher density intra network markets, airport delays will exceed those shown in this analysis.

Once the routing of aircraft among the 23 major cities was developed, a second program was used to generate schedules of aircraft departures between network city pairs. Using empirically derived time of day demand preferences, a set of departure "windows" was established for eacn domestic market, forcing departures at preferred or peak times but allowing broader variation in departure time during off-peak hours if necessary. Assigning departures within permissible "windows" to minimize the aircraft fleet size, the scheduling model produces an "Official Airline Guide" (OAG) type schedule for any planning period, using the fleet assignment model frequencies, time of day traffic demand preferences, and its own scheduling logic. As an example, the OAG generated by the model for Chicago O'Hare in the year 2000 is shown in Figure 4.2. 6/

The sequential routing and scheduling process described above was used to produce a series of OAG type time of day traffic profiles (comparable to the Chicago O'Hare (OAG) for each of the 25 primary air carrier airports in the 23 large hubs through the year 2000. These traffic forecasts were derived from FAA passenger enplanement projections. To check the accuracy of traffic forecasts, average daily air carrier operations predicted for 1975 were compared with observed 1974 scheduled traffic, as shown in Table 4.2. This comparison indicates the airport network model, given 1975 passenger enplanements, developed an aircraft operating schedule for the 23 largest hubs which was within 5 percent of the total scheduled commercial activity actually observed the previous year. 7/

On the basis of this closeness of fit, it was assumed the airport network model would predict traffic activity patterns reasonably well for all future years. Traffic forecasts derived by the airport network model for the planning period are shown in Table 4.3. It is noted that the threefold growth in air passenger demand anticipated by the year 2000 results in a less than proportional increase in aircraft operations. 8/ At some of the busiest airports, for example, annual growth rates for passengers and aircraft operations are 4 percent and 1 percent respectively. An explanation for this is that many of the larger markets are

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6/ The reader is referred to Appendix B for further discussion of the Airport Network Model developed for this analysis.

7/ Source of 1974 observed data was the May 15, 1974, OAG, a representative "average" schedule.

8/ See Table B.2 for passenger growth factors.

## FIGURE 4.2
## FORECAST SCHEDULE OF FLIGHT ARRIVALS AT CHICAGO OHARE

FAA UG3RD EVALUATION
COMPLEMENTARY POLICY STRATEGIES
OFFICE OF AVIATION POLICY

FORECAST YEAR 2000
BASE CASE SCENARIO
SCHEDULED OAG

To CHICAGO, ILL. CST ORD (O'HARE)

**From ATLANTA, GA. — EST ALT**

| Leave | Arrive |
|---|---|
| 6 40a | 7 10a |
| 7 45a | 8 15a |
| 8 30a | 9 00a |
| 10 10a | 10 40a |
| 10 50a | 11 20a |
| 11 50a | 12 20p |
| 13 00p | 13 30p |
| 14 20p | 14 50p |
| 15 25p | 15 55p |
| 16 20p | 16 50p |
| 17 10p | 17 40p |
| 17 55p | 18 25p |
| 18 35p | 19 05p |
| 19 25p | 19 55p |
| 20 20p | 20 50p |
| 22 00p | 22 30p |

**BOSTON, MASS. — EST ALT**

| Leave | Arrive |
|---|---|
| 6 50a | 7 50a |
| 8 00a | 9 00a |
| 8 55a | 9 55a |
| 10 05a | 11 05a |
| 11 15a | 12 15p |
| 12 30p | 13 30p |
| 13 25p | 14 25p |
| 14 25p | 15 25p |
| 15 35p | 16 35p |
| 16 30p | 17 30p |
| 17 15p | 18 15p |
| 17 50p | 18 50p |
| 18 30p | 19 30p |
| 19 15p | 20 15p |
| 20 00p | 21 00p |
| 21 00p | 22 00p |

**CLEVELAND, OH. — EST CLE**

| Leave | Arrive |
|---|---|
| 6 35a | 6 35a |
| 7 30a | 7 30a |
| 8 15a | 8 15a |
| 8 55a | 8 55a |
| 9 30a | 9 30a |
| 10 10a | 10 10a |
| 11 00a | 11 00a |
| 11 40a | 11 40a |
| 12 40p | 12 40p |
| 13 45p | 13 45p |
| 14 50p | 14 50p |
| 15 40p | 15 40p |
| 16 25p | 16 25p |
| 17 10p | 17 10p |
| 17 45p | 17 45p |
| 18 25p | 18 25p |
| 19 00p | 19 00p |
| 19 45p | 19 45p |
| 20 40p | 20 40p |
| 22 05p | 22 05p |

**DALLAS FT. WORTH, TEX. — CST DFW**

| Leave | Arrive |
|---|---|
| 6 35a | 8 30a |
| 7 20a | 9 15a |
| 7 55a | 9 50a |
| 8 25a | 10 20a |
| 8 55a | 10 50a |
| 9 20a | 11 15a |
| 9 50a | 11 45a |
| 10 20a | 12 15a |
| 10 55a | 12 50p |
| 11 30a | 13 25p |
| 12 05p | 14 00p |
| 12 40p | 14 35p |
| 13 20p | 15 15p |
| 14 10p | 16 05p |
| 15 10p | 17 05p |
| 16 20p | 18 15p |
| 17 40p | 19 35p |
| 19 00p | 20 55p |
| 20 20p | 22 15p |

**DENVER, COL. — MST DEN**

| Leave | Arrive |
|---|---|
| 6 25a | 9 30a |
| 7 10a | 10 15a |
| 7 35a | 10 40a |
| 8 00a | 11 05a |
| 8 20a | 11 25a |
| 8 40a | 11 45a |
| 9 05a | 12 10p |
| 9 20a | 12 25p |
| 9 45a | 12 50p |
| 10 05a | 13 10p |
| 10 30a | 13 35p |
| 10 50a | 13 55p |
| 11 15a | 14 20p |
| 11 50a | 14 55p |
| 12 10p | 15 15p |
| 12 35p | 15 40p |
| 13 00p | 16 05p |
| 13 35p | 16 40p |
| 14 10p | 17 15p |
| 14 55p | 18 00p |
| 15 40p | 18 55p |
| 16 35p | 19 40p |
| 17 35p | 20 40p |
| 18 35p | 21 40p |
| 19 30p | 22 35p |
| 20 20p | 23 25p |

CONT. NEXT COLUMN

To CHICAGO, ILL. CST CHI

**From DETROIT, MICH. — EST DET**

| Leave | Arrive |
|---|---|
| 6 20a | 6 10a |
| 7 10a | 7 00a |
| 7 40a | 7 30a |
| 8 10a | 8 00a |
| 8 35a | 8 25a |
| 9 05a | 8 55a |
| 9 30a | 9 20a |
| 9 55a | 9 45a |
| 10 30a | 10 20a |
| 11 00a | 10 50a |
| 11 30a | 11 20a |
| 12 05p | 11 55a |
| 12 45p | 12 35p |
| 13 35p | 13 25p |
| 14 20p | 14 10p |
| 15 00p | 14 50p |
| 15 35p | 15 25p |
| 16 05p | 15 55p |
| 16 35p | 16 25p |
| 17 30p | 17 20p |
| 17 55p | 17 45p |
| 18 25p | 18 15p |
| 18 50p | 18 40p |
| 19 15p | 19 05p |
| 19 45p | 19 35p |
| 20 25p | 20 15p |
| 21 10p | 21 00p |
| 22 20p | 22 10p |

**HOUSTON, TEX. — CST HOU**

| Leave | Arrive |
|---|---|
| 6 40a | 8 50a |
| 7 30a | 9 40a |
| 8 05a | 10 15a |
| 8 35a | 10 45a |
| 9 10a | 11 20a |
| 9 40a | 11 50a |
| 10 15a | 12 25p |
| 11 00a | 13 10p |
| 11 35a | 13 45p |
| 12 20p | 14 30p |
| 12 50p | 15 00p |
| 13 35p | 15 45p |
| 14 35p | 16 45p |
| 15 50p | 18 00p |
| 17 15p | 19 25p |
| 18 45p | 20 55p |
| 20 10p | 22 20p |

**KANSAS CITY, MO. — CST MKI**

| Leave | Arrive |
|---|---|
| 6 40a | 7 45a |
| 7 45a | 8 50a |
| 8 30a | 9 35a |
| 9 15a | 10 20a |
| 10 00a | 11 05a |
| 10 50a | 11 55a |
| 12 05p | 13 10p |
| 13 00p | 14 05p |
| 14 20p | 15 25p |
| 15 25p | 16 30p |
| 16 20p | 17 25p |
| 17 10p | 18 15p |
| 17 55p | 19 00p |
| 18 35p | 19 40p |
| 19 25p | 20 30p |
| 20 20p | 21 25p |
| 22 00p | 23 05p |

**LAS VEGAS, NEV. — PST LAS**

| Leave | Arrive |
|---|---|
| 6 20a | 11 30a |
| 7 00a | 12 10p |
| 7 35a | 12 45p |
| 8 05a | 13 15p |
| 8 35a | 13 45p |
| 9 05a | 14 15p |
| 9 40a | 14 50p |
| 10 10a | 15 20p |
| 10 45a | 15 55p |
| 11 20a | 16 30p |
| 12 00p | 17 10p |
| 12 30p | 17 40p |
| 13 10p | 18 20p |
| 13 55p | 19 05p |
| 14 45p | 19 55p |
| 16 00p | 21 10p |

**LOS ANGELES, CAL. — PST LAX**

| Leave | Arrive |
|---|---|
| 6 10a | 11 50a |
| 6 30a | 12 50a |
| 7 00a | 12 40p |
| 7 15a | 12 55p |
| 7 30a | 13 10p |
| 7 45a | 13 25p |
| 8 00 | 13 40p |
| 8 15a | 13 55p |
| 8 30a | 14 10p |
| 8 45a | 14 25p |
| 9 00a | 14 40p |
| 9 15a | 14 55p |
| 9 30a | 15 10p |
| 9 45a | 15 25p |
| 10 05a | 15 45p |
| 10 20a | 16 00p |
| 10 40a | 16 20p |
| 10 55a | 16 35p |
| 11 10a | 16 50p |
| 11 30a | 17 10p |
| 11 45a | 17 25p |
| 12 05p | 17 45p |
| 12 25p | 18 05p |
| 12 40p | 18 20p |

CONT. NEXT COLUMN

To CHICAGO, ILL. CST CHI

**From LOS ANGELES, CAL.-CONT. — PST LAX**

| Leave | Arrive |
|---|---|
| 13 00p | 18 40p |
| 13 20p | 19 00p |
| 13 45p | 19 25p |
| 14 05p | 19 45p |
| 14 30p | 20 10p |
| 15 00p | 20 40p |
| 15 35p | 21 15p |
| 16 25p | 22 05p |

**MIAMI, FLA. — EST MIA**

| Leave | Arrive |
|---|---|
| 6 50a | 8 30a |
| 8 00a | 9 40a |
| 8 55a | 10 35a |
| 9 55a | 11 35a |
| 11 20a | 13 00p |
| 12 35p | 14 15p |
| 13 30p | 15 10p |
| 14 25p | 16 05p |
| 15 35p | 17 15p |
| 16 30p | 18 10p |
| 17 15p | 18 55p |
| 17 50p | 19 30p |
| 18 30p | 20 10p |
| 19 15p | 20 55p |
| 20 00p | 21 40p |
| 21 00p | 22 40p |

**MINNEAPOLIS, MINN. — CST MSP**

| Leave | Arrive |
|---|---|
| 6 30a | 7 30a |
| 7 15a | 8 15a |
| 7 55a | 8 55a |
| 8 25a | 9 25a |
| 8 55a | 9 55a |
| 9 25a | 10 25a |
| 9 55a | 10 55a |
| 10 30a | 11 30a |
| 11 05a | 12 05p |
| 11 50a | 12 50p |
| 12 30p | 13 30p |
| 13 30p | 14 30p |
| 14 20p | 15 20p |
| 15 05p | 16 05p |
| 15 45p | 16 45p |
| 16 20p | 17 20p |
| 16 55p | 18 55p |
| 17 25p | 18 25p |
| 17 55p | 18 55p |
| 18 25p | 19 25p |
| 18 55p | 19 55p |
| 19 30p | 20 30p |
| 20 10p | 21 10p |
| 21 00p | 22 00p |
| 22 15p | 23 15p |

**NEW ORLEANS, LA. — CST MSY**

| Leave | Arrive |
|---|---|
| 7 15a | 9 15a |
| 8 45a | 10 45a |
| 10 00a | 12 00p |
| 11 30a | 13 30p |
| 13 25p | 15 25p |
| 15 40p | 17 40p |
| 19 10p | 21 10p |

**NEW YORK, N. Y. — EST NYC**

| Leave | Arrive |
|---|---|
| 6 10a | 6 35a |
| 6 40a | 7 05a |
| 7 05a | 7 30a |
| 7 20a | 7 45a |
| 7 30a | 7 55a |
| 7 45a | 8 10a |
| 8 00a | 8 25a |
| 8 15a | 8 40a |
| 8 25a | 8 50a |
| 8 40a | 9 05a |
| 8 50a | 9 15a |
| 9 05a | 9 30a |
| 9 20a | 9 45a |
| 9 35a | 10 00a |
| 9 50a | 10 15a |
| 10 10a | 10 35a |
| 10 30a | 10 55a |
| 10 55a | 11 20a |
| 11 10a | 11 35a |
| 11 30a | 11 55a |
| 11 45a | 12 10p |
| 12 00p | 12 25p |
| 12 15p | 12 40p |
| 12 30p | 12 55p |
| 12 45p | 13 10p |
| 13 00p | 13 25p |
| 13 15p | 13 40p |
| 13 25p | 13 50p |
| 13 40p | 14 05p |
| 13 50p | 14 15p |
| 14 05p | 14 30p |
| 14 20p | 14 45p |
| 14 35p | 15 00p |
| 14 50p | 15 15p |
| 15 05p | 15 30p |
| 15 25p | 15 50p |
| 15 40p | 16 05p |
| 15 55p | 16 20p |
| 16 05p | 16 30p |
| 16 20p | 16 45p |
| 16 30p | 16 55p |
| 16 40p | 17 05p |
| 16 50p | 17 15p |
| 17 00p | 17 25p |
| 17 10p | 17 35p |

CONT. NEXT COLUMN

To CHICAGO, ILL. CST CHI

**From NEW YORK, N. Y.-CONT. — EST NYC**

| Leave | Arrive |
|---|---|
| 17 20p | 17 45p |
| 17 30p | 17 55p |
| 17 35p | 18 00p |
| 17 45p | 18 10p |
| 17 55p | 18 20p |
| 18 05p | 18 30p |
| 18 15p | 18 40p |
| 18 25p | 18 50p |
| 18 35p | 19 00p |
| 18 45p | 19 10p |
| 18 50p | 19 15p |
| 19 05p | 19 30p |
| 19 15p | 19 40p |
| 19 25p | 19 50p |
| 19 35p | 20 00p |
| 19 50p | 20 15p |
| 20 00p | 20 25p |
| 20 10p | 20 35p |
| 20 25p | 20 50p |
| 20 35p | 21 00p |
| 20 50p | 21 15p |
| 21 05p | 21 30p |
| 21 25p | 21 50p |

**PHILADELPHIA, PA. — EST PHL**

| Leave | Arrive |
|---|---|
| 6 40a | 7 20a |
| 7 35a | 8 15a |
| 8 20a | 9 00a |
| 9 05a | 9 45a |
| 9 50a | 10 30a |
| 10 55a | 11 35a |
| 11 55a | 12 35p |
| 12 45p | 13 25p |
| 13 25p | 14 05p |
| 14 10p | 14 50p |
| 14 55p | 15 35p |
| 15 50p | 16 30p |
| 16 30p | 17 10p |
| 17 05p | 17 45p |
| 17 30p | 18 10p |
| 18 00p | 18 40p |
| 18 35p | 19 15p |
| 19 05p | 19 45p |
| 19 40p | 20 20p |
| 20 20p | 21 00p |
| 21 05p | 21 45p |

**PITTSBURG, PA. — EST PIT**

| Leave | Arrive |
|---|---|
| 6 30a | 6 35a |
| 7 25a | 7 30a |
| 8 05a | 8 10a |
| 8 40a | 8 45a |
| 9 15a | 9 20a |
| 9 50a | 9 55a |
| 10 30a | 10 35a |
| 11 05a | 11 10a |
| 11 45a | 11 50a |
| 12 45p | 12 35p |
| 13 50p | 13 55p |
| 14 45p | 14 50p |
| 15 35p | 15 40p |
| 16 15p | 16 20p |
| 16 55p | 17 00p |
| 17 30p | 17 35p |
| 18 05p | 18 10p |
| 18 40p | 18 45p |
| 19 25p | 19 30p |
| 19 55p | 20 00p |
| 20 50p | 20 55p |
| 22 10p | 22 15p |

**SAN FRANCISCO, CAL. — PST SFO**

| Leave | Arrive |
|---|---|
| 6 30a | 12 20p |
| 7 15a | 13 05p |
| 7 40a | 13 30p |
| 8 05a | 13 55p |
| 8 20a | 14 10p |
| 8 40a | 14 30p |
| 9 00a | 14 50p |
| 9 20a | 15 10p |
| 9 35a | 15 25p |
| 9 55a | 15 45p |
| 10 15a | 16 05p |
| 10 40a | 16 30p |
| 11 00a | 16 50p |
| 11 20a | 17 10p |
| 11 45a | 17 35p |
| 12 10p | 18 00p |
| 12 50p | 18 40p |
| 13 30p | 19 20p |
| 14 30p | 20 20p |
| 15 35p | 21 25p |

**SEATTLE, WASH. — PST SEA**

| Leave | Arrive |
|---|---|
| 6 25a | 12 00p |
| 7 15a | 12 50p |
| 7 45a | 13 20p |
| 8 20a | 13 55p |
| 8 55a | 14 30p |
| 9 35a | 15 10p |
| 10 10a | 15 45p |
| 10 50a | 16 25p |
| 11 30a | 17 05p |
| 12 10p | 17 45p |
| 12 50p | 18 25p |
| 13 35p | 19 10p |
| 14 35p | 20 10p |
| 15 55p | 21 30p |

# TABLE 4.2
# FLEET ASSIGNMENT MODEL VALIDITY CHECK

FAA UG3RD EVALUATION
COMPLEMENTARY POLICY STRATEGIES
OFFICE OF AVIATION POLICY

COMPARISON OF INTRA NETWORK
TRAFFIC FORECASTS WTIH ACTUAL
AIRCRAFT ACTIVITY

| HUB | SCHEDULED AIR CARRIER DEPARTURES, ACTUAL DATA[1/] | FLEET ASSIGNMENT MODEL FORECASTS[1/] | PERCENT ACCURACY (±) |
|---|---|---|---|
| NYC | 373 | 370 | 0.2% |
| ORD | 353 | 369 | 4.5 |
| WAS | 273 | 233 | 14.7 |
| LAX | 191 | 219 | 14.7 |
| ATL | 178 | 165 | 7.3 |
| DFW | 172 | 144 | 16.3 |
| PHL | 156 | 98 | 37.2 |
| BOS | 151 | 146 | 3.3 |
| SFO | 145 | 165 | 13.8 |
| PIT | 133 | 77 | 42.1 |
| STL | 119 | 111 | 6.7 |
| CLE | 116 | 88 | 24.1 |
| MIA | 115 | 98 | 14.8 |
| DEN | 113 | 116 | 2.7 |
| DTW | 110 | 115 | 4.5 |
| IAH | 101 | 75 | 25.4 |
| MSP | 86 | 81 | 5.8 |
| LAS | 75 | 81 | 8.0 |
| MCI | 71 | 78 | 9.9 |
| MST | 67 | 63 | 6.0 |
| TPA | 65 | 86 | 32.3 |
| SEA | 55 | 60 | 9.1 |
| HNL | 26 | 44 | 69.2 |
| TOTAL | 3244 | 3082 | ± 5.0% |

[1/] DAILY DEPARTURES TO 23 CITY NETWORK DESTINATIONS

## TABLE 4.3
## FORECAST AIR CARRIER DAILY OPERATIONS 1/

FAA UG3RD EVALUATION
COMPLEMENTARY POLICY STRATEGIES
OFFICE OF AVIATION POLICY

| AIRPORT | 1985 | 1990 | 1995 2/ | 2000 2/ |
|---|---|---|---|---|
| ORD | 1842 | 1875 | 2030 (1875) | 2215 (1875) |
| BOS | 815 | 900 | 1000 (1000) | 1150 (1150) |
| SFO | 843 | 915 | 995 (965) | 1095 (1098) |
| STL | 576 | 708 | 830 (825) | 909 (904) |
| DEN | 738 | 933 | 970 (975) | 1065 (1035) |
| LAX | 1133 | 1253 | 1502 (1502) | 1725 (1715) |
| SEA | 573 | 580 | 610 (600) | 695 (710) |
| PHL | 481 | 519 | 565 (565) | 750 (685) |
| CLE | 452 | 470 | 530 (555) | 585 (610) |
| NYC 3/ | 1665 | 1745 | 1885 (1885) | 2200 (2160) |
| ATL | 1100 | 1200 | 1220 (1240) | 1315 (1310) |
| MSY | 438 | 475 | 500 (505) | 570 (560) |
| MSP | 518 | 550 | 625 (625) | 665 (665) |
| DTW | 596 | 650 | 690 (665) | 785 (665) |
| MCI | 503 | 555 | 665 (680) | 810 (785) |

1/ Derived from FAA passenger enplanement forecasts

2/ Activity levels in parentheses indicate air carrier operations for peak pricing and quota scenario (#2).

3/ Includes JFK, LGA, EWK

already receiving frequent service, and much of the predicted passenger growth is accommodated with larger aircraft instead of increased flight frequency. In addition, there is a tendency towards more point-to-point or direct service, eliminating some of the multistop routes. Wide-body aircraft utilization and direct routing of flights result in less airport activity than would be anticipated from simple assessments.

For all the airports in the 23 hub network, four different 25-year traffic histories were developed, one representing the average time of day traffic profile associated with each of the four scenarios introduced earlier in this chapter. Equivalent numbers of passengers were carried on respective markets in each scenario. The unique provisions of each scenario, however, resulted in four different traffic patterns for each airport and time period.

Airport delays resulting from each traffic distribution (i.e., scenario) were computed from a delay prediction program based upon advanced queving theory. 9/ The air carrier delays accumulated at Chicago O'Hare, for example, are shown in Figure 4.1. Delays were computed for all airports in the network for 1975, 1985, and at 5 year intervals thereafter through the year 2000. These delays were aggregated by scenario, with results as presented in Figure 4.3.

When overall airport system delays under each of the four scenarios are compared, differences may be attributed to the unique features of each scenario. The impact of the UG3RD on airport congestion, for example, may be contrasted with peak-time pricing and quotas by comparing total system delays accumulated under respective scenarios shown in Figure 4.3.

Another measure of system capacity and/or service quality is the rate of flight cancellations at an airport. As explained earlier, under certain heavy traffic conditions,

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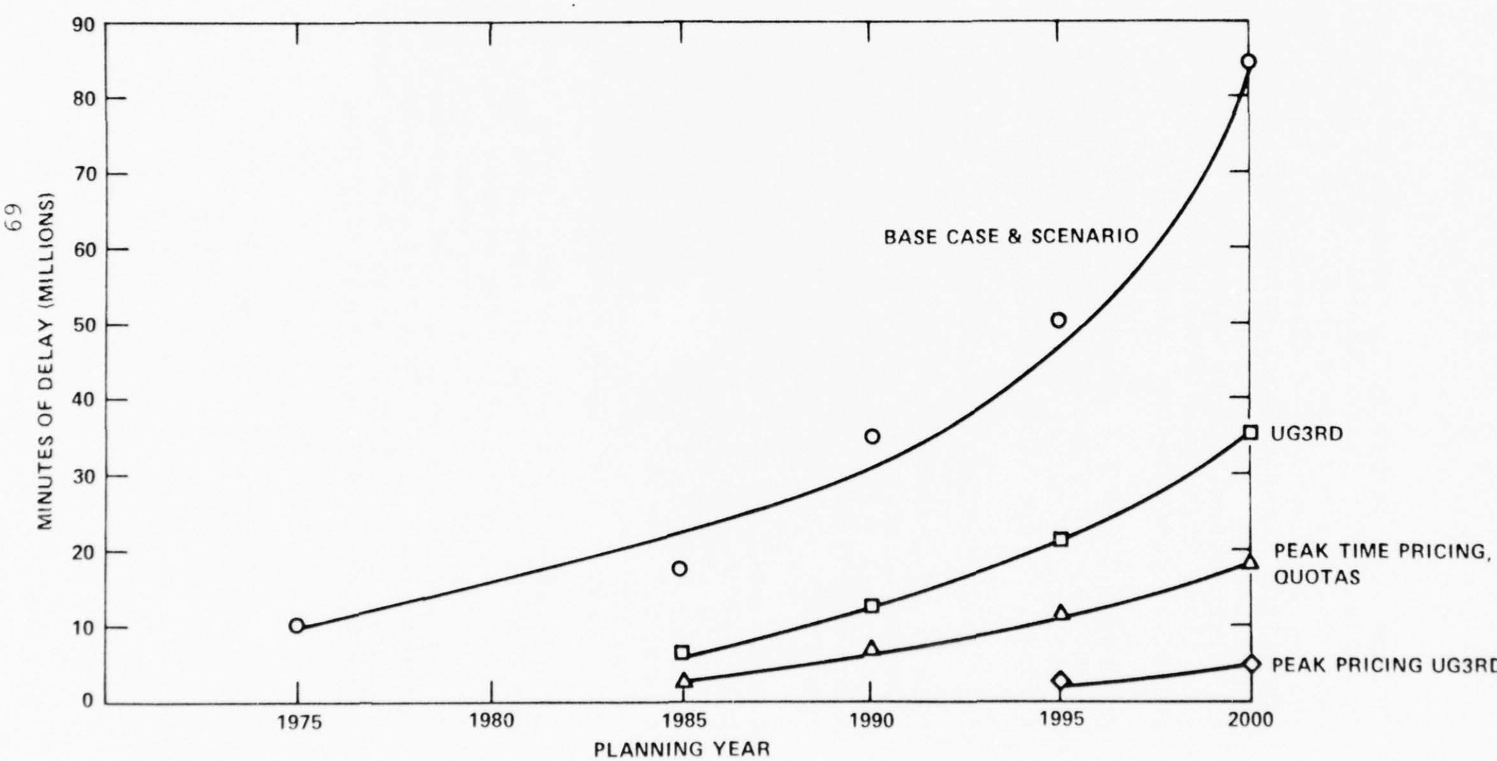
9/ For a description of this program, the reader is referred to Time Dependent Estimates of Delays and Delay Costs At Major Airports, Hengsbach and Odoni, Massachusetts Institute of Technology, January 1975, [49].

## FIGURE 4.3

## TOTAL ANNUAL AIR CARRIER DELAY 25 AIRPORT SYSTEM

FAA UG3RD EVALUATION
COMPLEMENTARY POLICY STRATEGIES
OFFICE OF AVIATION POLICY

SYSTEM DELAYS UNDER
ALTERNATIVE SCENARIOS



flights were cancelled in order to avoid situations of unrealistically large delays. These cancellations may inconvenience air travellers and/or airline operators, and may be viewed as a disbenefit. Each scenario has its own unique traffic distribution and, consequently, its unique flight cancellation rate. The projected occurrence of flight cancellations under the UG3RD may be contrasted with those under peak pricing and quotas by comparing projected cancellation rates shown in Figure 4.4.

Figures 4.3 and 4.4 represent summary results of the analysis of pricing and administrative alternatives to the UG3RD. Significant findings and conclusions which emerge from this information are presented in the following section.

### 4.1.4 Discussion of Results

Peak pricing and quotas were found to be effective as a method of reducing air carrier congestion and delay. In fact, there were fewer delays at primary large hub airports under a system of pricing and administrative alternatives than there were as a result of UG3RD airport capacity improvements. This is shown in Figure 4.3, where, at any time in the 25-year period, 1975-2000, annual system delays under a peak pricing and quota scenario were less than delays which would be anticipated if UG3RD improvements were implemented. Moreover, Figure 4.4 shows that congestion experienced in a peak pricing and quota scenario forced fewer cancellations of air carrier flights than there were when airport capacities were improved with UG3RD technological features.

Of all cases examined, minimum airport congestion and delay was observed when UG3RD improvements were combined with a schedule of peak pricing and quotas. This was shown at a single airport as well as throughout the airport network. It is concluded therefore, that peak-hour pricing and quota alternatives would effectively complement the technological features of the UG3RD, and improve the flow of air traffic between the primary large hub airports.

The discounted costs of airport system delay (airline direct operating expenses and passenger inconvenience) were computed through the year 2000 at the top 25 airports, with results shown in Table 4.4. 10/ This analysis finds that the UG3RD could eliminate approximately 50 percent of airport delay costs which might otherwise be anticipated over that period. In comparison, peak pricing and quotas could eliminate almost 65 percent of the unnecessary costs of delay. 11/ A peak-load pricing schedule implemented in concert with the UG3RD technological improvements could eliminate almost 80 percent of the cost of air carrier delays anticipated at the 25 largest airports for the next 25 years.

There are limiting characteristics of the peak pricing and quota options, however, that must be reviewed. For example, airport quotas and other purely administrative measures, while found effective in dealing with congestion problems, tend to be biased toward maintaining the status quo when used over a protracted period of time. Because economic value is not fully taken into consideration in the implementation of a quota system, an environment can be created which: (1) Protects those with rights to time slots from being displaced by others who may derive a higher economic value from the same time slots; and (2) Prevents the airport from obtaining through economic mechanisms the information required to determine the need for capacity expansion or for an improved quality of service.

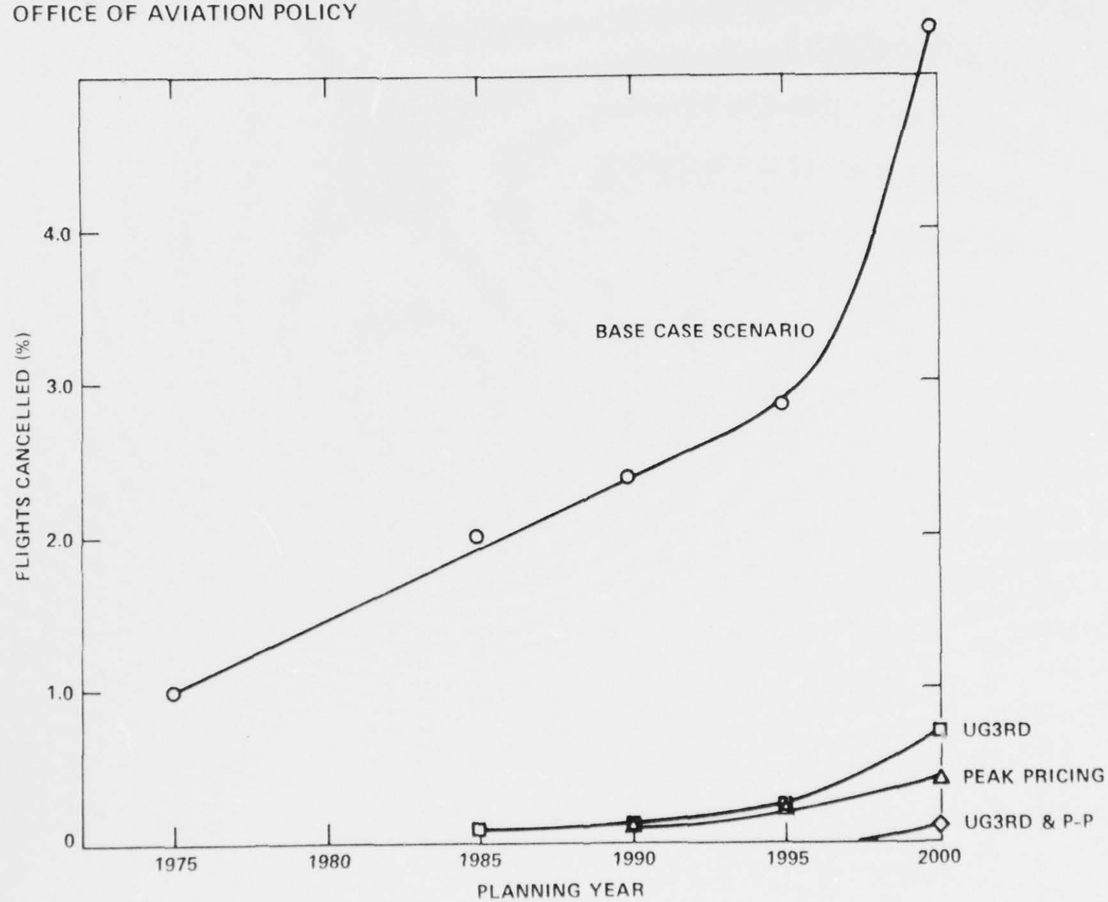
Administrative limitations on the use of an airport, by keeping demand within acceptable bounds, assures the relatively smooth operation of the facility. In effect, severe congestion can be disallowed. This state of affairs can be maintained indefinitely. However, with access to the airport restricted and with potential users unable to indicate the true value to them of airport capacity expansion, a false sense of well-being can be conveyed. In effect, by arbitrarily constraining

10/ Using actual 1975 aircraft direct operating expenses, and assuming passenger time valued at $12.50 per hour.

11/ Pricing and administrative policy options do have a cost in terms of passenger convenience. That is, with less seats available in the peak hours, fewer passengers travel at preferred times. It is estimated that in the peak pricing and quota scenario, up to 20 percent of all passengers were displaced up to 2 hours from their desired travel time. No one, however, was forced to fly between 12:00 p.m. and 6:00 a.m. in any scenario.

## FIGURE 4.4
## PROJECTED FLIGHT CANCELLATION RATES AT THE 25 MAJOR AIR CARRIER AIRPORTS

FAA UG3RD EVALUATION
COMPLEMENTARY POLICY STRATEGIES
OFFICE OF AVIATION POLICY



## TABLE 4.4
## DISCOUNTED COST OF AIR CARRIER DELAY IN THE 25 AIRPORT SYSTEM THROUGH THE YEAR 2000

FAA UG3RD EVALUATION
COMPLEMENTARY POLICY STRATEGIES
OFFICE OF AVIATION POLICY

| SCENARIO | DELAY COSTS[1/] ($ MILLIONS) |
|---|---|
| BASE CASE | $7107 |
| PEAK PRICING AND QUOTAS | 2489 |
| UG3RD | 3540 |
| PEAK PRICING & UG3RD | 1504 |

[1/]AIRCRAFT AND PASSENGER DELAY DISCOUNTED AT 10% TO 1975 DOLLARS

demand, artificial equilibrium conditions can be created which, in the long run, may have distorting effects on the nature, quality and cost of the transportation service provided.

Similarly, the realities of a peak-load pricing system must be closely examined. The theory of peak pricing is very persuasive. Moreover, experience has shown that a peak-pricing schedule can shift some airport user demand patterns, as demonstrated in the New York Port Authority case.

While the basic arguments which support peak-time pricing have been thoroughly reviewed in the technical literature, in practice there are significant problems relating to implementation of peak-pricing schedules. For example, there is no accurate method for determining the optimal pricing structures, due primarily to the formidable problem of estimating elasticities and cross elasticities of airport demand to usage charges. The Heathrow case study described earlier in this chapter showed that airlines were relatively insensitive to peak-time charges imposed at that airport. Little additional information on the impact of peak-landing fees on air carriers is available.

There are some institutional issues as well that must be resolved before a peak-time pricing system could be widely adopted. For example, should peak-load charges be imposed by the FAA or the local sponsor? Could a peak-time pricing schedule be integrated with airport pricing agreements now in effect? Typically, airlines and airport sponsors negotiate landing fee schedules, often on a long-term basis. If neither party favored a peak pricing strategy, it is not clear how it would be instituted.

Perhaps more importantly, would the large charges needed to shift demand be politically acceptable? By design, peak pricing does not consider ability to pay. During periods of congestion, peak prices would be hard or impossible to bear for certain kinds of aviation users, such as general aviation, air taxi, commuters, and perhaps nonscheduled operators. This is consistent with desired effects of a peak-pricing policy, of course. Those continuing to use the airport will be the ones who derive the highest benefit. However, such a pricing policy represents a radical departure from the traditional practice of free access to national aviation facilities and services. Not all sectors of the aviation community are likely to agree with such a change.

In the long run, these economic and institutional constraints may be a determining factor in the peak-time pricing issue. If the constraints are overcome, peak pricing could emerge as a more realistic alternative for the National Airspace System.

## 4.2 Increased Utilization of Satellite Airports

The use of satellite or secondary airports has often been considered as one of the most economical means of relieving the increasing congestion of many of the major commercial airports serving the principal metropolitan areas of the country. There exist, in close proximity to most of these metropolitan areas, a number of under-utilized or potentially available airports which could with a minimum investment support a portion of the air traffic which has created the congestion at the principal hub airport. A substantial diversion of general aviation and commercial traffic to these satellite airports would have a beneficial impact on airport system delay.

In most cases, however, efforts to develop satellite airports have resulted in little success as the airlines providing the air transportation and the traveling public tend to shun satellite facilities and congregate at the primary hub airports. Previous studies have been able to confirm and to some degree quantify the existence of this public preference and the economic pressures on the air carriers to concentrate at a single airport. Indeed, some researchers have concluded that there is little hope in attempting to develop a system of satellite airports. 12/

Yet, there has been some degree of success in a few areas. The most noticeable of these is the Los Angeles--San Francisco Bay area city-pair where more than 20 percent of the total air traffic is using satellite airports. Furthermore, the degree of congestion at major airports along with the increasing cost of fuel has placed a much higher premium on achieving a solution to the airport delay problem. The purpose of this section is to examine the potential benefits of expanded utilization of the satellite airports in each large hub.

### 4.2.1 Analytical Approach

The diversion of significant numbers of aircraft operations away from congested commercial airports to under-utilized facilities in major metropolitan areas is constrained by a multiplicity of factors. Some of these factors are described in Table 4.5. This analysis considered each factor described in Table 4.5 as a potential constraint to expanded satellite airport usage.

12/ Gelerman, Walter and Neufville, Richard de, "Planning for Satellite Airports, "Transportation Engineering Journal, August 1973, page 537 , [27].

## TABLE 4.5

## CONSTRAINTS TO EXPANDED UTILIZATION OF SATELLITE AIRPORTS

FAA UG3RD EVALUATION
COMPLEMENTARY POLICY STRATEGIES
OFFICE OF AVIATION POLICY

| CONSTRAINT | | DEFINITION OF CRITERIA | |
|---|---|---|---|
| 1. | AIRPORT CHARACTERISTICS | 1.1 | CURRENT TRAFFIC LEVELS AT OR ABOVE MAXIMUM AIRPORT CAPACITY. |
| | | 1.2 | RUNWAY LENGTH AND WEIGHT BEARING CAPABILITY BELOW STANDARDS FOR AIRCRAFT TYPE. |
| 2. | LOCAL TRANSPORTATION INTRASTRUCTURE | 2.1 | DRIVING TIME TO SATELLITE FACILITY IN EXCESS OF ONE HOUR FROM CBD. |
| 3. | AIR TRAFFIC CONTROL SYSTEM (ATC) | 3.1 | CONFLICTS WITH FAA ORDER 7480.1A: GUIDELINES FOR AIRPORT SPACING AND TRAFFIC PATTERN AIRSPACE AREAS, AUGUST 3, 1971. |
| 4. | MILITARY REQUIREMENTS | 4.1 | MILITARY PREEMPTION OF FACILITY. |
| | | 4.2 | COMMERCIAL AND/OR PRIVATE CIVILIAN TRAFFIC NOT AUTHORIZED UNDER OFFICIAL JOINT USE AGREEMENT. |
| 5. | MARKET FACTORS | 5.1 | PUBLIC PREFERENCE FOR PRIMARY AIRPORT. |
| | | 5.2 | ECONOMICS OF AIR CARRIER OPERATION. |
| 6. | POLITICAL FACTORS | 6.1 | ORGANIZED CITIZEN OPPOSITION TO AIRPORT EXPANSION BASED UPON ENVIRONMENTAL CONCERNS AND OTHER FACTORS |
| | | 6.2 | PROBLEMS WITH MULTIJURISDICTIONAL GOVERNMENTS. |
| 7. | LEGAL/LEGISLATIVE | 7.1 | ZONING OR STATUTE LIMITATIONS ON AIRPORT UTILIZATION OF EXPANSION. |
| 8. | FINANCIAL | 8.1 | INABILITY OF AIRPORT SPONSOR TO FINANCE AIRPORT OPERATION AND/OR EXPANSION. |

In order to derive a listing of airport candidates for expansion or increased utilization, all possible airports in the vicinity (90 mile square centered on the Central Business District) of the 23 hub areas were evaluated. For each, aircraft type acceptance capabilities were assessed by examining maximum aircraft main gear wheel loads and runway lengths. Possible airspace conflicts were then identified by geometric analysis of the protected approach and departure tracks at each airport, and for all the navigation facilities commonly used. 13/

Constraints to expanded airport utilization which were imposed by the local transportation infrastructure were estimated through use of highway road maps and highway and freeway driving speeds and travel times provided by the Urban Mass Transit Administration and the National Highway Transportation Safety Administration. 14/

Military constraints to expanded utilization of selected satellite airports were identified by the Department of Defense Airport Working Group at FAA's request. 15/ The Office of the Secretary of Defense (OSD) provided a listing of the joint use potential of military airfield facilities for the 1980-1990 timeframe.

13/ This phase of the analysis was facilitated by the use of specially designed airspace templates which were superimposed over terminal area charts in each hub. Airspace requirements were identified in Department of Transportation, Federal Aviation Administration, U.S. Standard for Terminal Instrument Procedures (TERPS), February 1970, [83]. Also, Order 7480.1A, Guidelines for Airport Spacing and Traffic Pattern Airspace Areas," August 1971, [82].

14/ "A Preliminary Look at Ground Access to Airport," Steiner M. Silence, Highway Research Record, January 1973, pages 14-20. The analysis set forward in this reference provided the format for the evaluation of the local transportation infrastructure.

15/ OSD letter of September 11, 1975. Thomas S. Falatko, DOD Liaison Officer to the FAA.

Each large hub was evaluated to determine what marketing factors affected the viability of developing a satellite airport system. As noted, there is a tendency for the traveling public to congregrate at major airports and, as a consequence, for the airlines to concentrate flight service at those airports in order to maximize their individual market shares and revenues. These tendencies and the rationale supporting them were examined to determine the possibilities which might exist to overcome this motivation and successfully develop satellite airports. 16/

16/ Analysis of the Marketing Factors Which Impact The Development of Satellite Airport Operations, draft report, Nicholas P. Krull, October 1975, [36].

Finally, political, legal, and financial constraints to satellite airport use were identified through interviews conducted with approximately 30 FAA representatives in each of the 23 large hubs. Where available, local planning documents were requested and studied. Where master plans and other documents were unavailable, Metropolitan Planning Organization (MPO) officials were contacted regarding expansion plans. Interviews with approximately 40 additional planning officials were conducted for this purpose. Interviews with 25 airport managers were conducted to complete the field data. 17/

Each of the constraints discussed above (e.g., ATC, political, legal, financial) was considered a potential limitation to expanded satellite airport usage. As necessary, airports were removed as unsuitable candidates. Starting from an original listing of over 12,000 landing facilities, approximately 375 satellite airports were identified which, on the basis of evaluation criteria selected for this analysis, appeared to offer potential for expanded use. The most promising of these airports are shown in Table 4.6.

Capacity limitations and current operating levels of the satellite candidates in each hub were determined in order to ascertain the potential additional capacity available for off-loading congested air carrier airports. Assuming maximum diversion of traffic away from the congested airport (as a result, say, of a pricing or administrative action) aircraft delays at the primary air carrier airport in each hub were estimated before and after expanded satellite airport use. Results of this exercise are shown in Figure 4.5. 18/

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17/ The environmental compatibility of satellite airport expansion was appraised during these interviews. It is recognized, however, that the full impact of environmental constraints can be assessed only after submittal and subsequent review of an impact statement. Consequently, this report may underestimate the environmental constraints to satellite airport use.

18/ It is noted that this analysis is not an action plan for air traffic diversion, but an assessment of additional airport capacity available at satellite facilities.

## TABLE 4.6

## • SATELLITE AIRPORT CANDIDATES

FAA UG3RD EVALUATION
COMPLEMENTARY POLICY STRATEGIES
OFFICE OF AVIATION POLICY

AIRPORTS WITH
POTENTIAL FOR
EXPANDED USE

**CHICAGO HUB**

| | |
|---|---|
| CLOW INTERNATIONAL | LANGER |
| FRANKFORT | LENOX HOWELL |
| GARY | MIDWAY |
| GEAR | WAUKEEGAN |

**LOS ANGELES HUB**

| | |
|---|---|
| AGUA DULCE | PALMDALE |
| COMPTON | SAN FERNANDO |
| HAWTHORNE | SANTA SUZANNA |
| ONTARIO | WHITEMAN |

**ATLANTA HUB**

| | |
|---|---|
| BEAR CREEK | FULTON COUNTY |
| BERRY HILL | GWINETTE COUNTY |
| COVINGTON MUNI | McCOLLUM |
| DE KALB | SOUTH EXPRESSWAY |
| | STONE MOUNTAIN |

**NEW YORK HUB**

| | |
|---|---|
| CALDWELL-WRIGHT | NEWARK |
| GRUMMAN-BETHPAGE | PRESTON |
| ISLIP | RAMAPO VALLEY |
| KUPPER | REPUBLIC |
| LINDEN | SOMERSET HILLS |
| NAIROBI | WESTCHESTER COUNTY |

**SAN FRANCISCO HUB**

| | |
|---|---|
| FREEMONT | OAKLAND |
| GNOSS | PALO ALTO |
| HALFMOON BAY | SMITH RANCH |
| LIVERMORE | SOUTH COUNTY |
| NAPA COUNTY | TRAVIS AFB |

**DALLAS FT. WORTH HUB**

| | |
|---|---|
| ARLINGTON | MANGHAM FIELD |
| BLUE HOUND | MEECHAM FIELD |
| GRAND PRAIRIE | RED BIRD |
| OAK GROVE | SAGINAW |

**WASHINGTON, D.C. HUB**

| | |
|---|---|
| BALTIMORE WASHINGTON INTERNATIONAL | LEE |
| | MANASSAS |
| COLLEGE PARK | MARYLAND |
| DAVIS | MONTGOMERY COUNTY |
| DULLES | P. G. COUNTY |
| FREEWAY | SUBURBAN |
| GLEN L. MARTIN | |

**MIAMI**

| | |
|---|---|
| BOCA RATON | NEW TAMAIMI |
| FT. LAUDERDALE EXECUTIVE | OPA LOCKA WEST |
| | POMPANO BEACH |
| FT. LAUDERDALE HOLLYWOOD | |

**BOSTON HUB**

| | |
|---|---|
| BEVERLY MUNI | MARSHFIELD |
| GRENIER FIELD | MIDDLEBORO |
| HAVER HILL | NORFOLK |
| LAWRENCE MUNI | TEW MAC |
| MANSFIELD MUNI | T.F. GREEN STATE |
| | WORCESTER |

**DENVER HUB**

| | |
|---|---|
| ARAPAHOE COUNTY | JEFFCO |
| BOULDER MUNI | LONGMOUNT |
| FT. COLLINS | MARSHDALE |

**HONOLULU HUB**

| | |
|---|---|
| FORD ISLAND | |

**DETROIT HUB**

| | |
|---|---|
| ANN ARBOR MUNI | McKINLEY |
| BERZ-McCOMB | NEW HUDSON |
| BIG BEAVER | OAKLAND ORION |
| BISHOP | OAKLAND PONTIAC |
| CUSTER | SALEM |
| DETROIT CITY | TOLEDO EXPRESS |
| GROSSE ISLE | WILLOW RUN |

**PHILADELPHIA HUB**

| | |
|---|---|
| BRIDGEPORT | NAFEC |
| BUGHL FIELD | PERKIOMEN VALLEY |
| BURLINGTON COUNTY | RED LION |
| CROSS KEYS | TURNER FIELD |
| HAMMONTON | WILMINGTON |
| MERCER COUNTY | WINGS FIELD |
| MONTGOMERYVILLE | |

**PITTSBURGH HUB**

| | |
|---|---|
| ALLEGHENY COUNTY | GLADE MILL |
| BANDEL | HERRON |
| BEAVER COUNTY | LATROBE |
| BUTLER-GRAHAM | RESTRAVER |
| BUTLER SHOW | WASHINGTON COUNTY |
| CAMPBELL | ZELIOENOPLE-MUNI |

**ST LOUIS HUB**

| | |
|---|---|
| ARROWHEAD | ST. CHARLES |
| BI STATE PARKS | ST. CHARLES SMART |
| CIVIC MEMORIAL | SPIRIT OF ST LOUIS |
| CREVE COVER | WEISS |
| FESTUS MEMORIAL | |

**MINNEAPOLIS HUB**

| | |
|---|---|
| AIRLAKE | LAKE ELMO |
| ANOKA | ST. PAUL DOWNTOWN |
| CRYSTAL | SOUTH ST. PAUL |
| FLYING CLOUD | |

**CLEVELAND HUB**

| | |
|---|---|
| BOSWORTH | FORE PAUGH |
| BURKE LAKE FRONT | FREEDOM FIELD |
| CASEMENT | LORIAN COUNTY |
| CHAGRIN FALLS | LOST NATION |
| CONCORD | PATTON |
| CUYAHOGA FALLS | THOMPSON |

**HOUSTON HUB**

| | |
|---|---|
| AN DRAU AIR PARK | GENOA |
| CLEAR LAKE | HUMPHREY |
| EXPRESS | |

**LAS VEGAS HUB**

| | |
|---|---|
| BOULDER CITY | JEAN |
| HENDERSON SKY HARBOR | NORTH LAS VEGAS |

**SEATTLE HUB**

| | |
|---|---|
| KITSAP COUNTY | SNOHOMISH COUNTY |
| PORT ORCHARD | SPANAWAY |
| PUYALLUP | TACOMA INDUSTRIAL |
| RENTON | |

**TAMPA HUB**

| | |
|---|---|
| ALBERT WITTED | PLANT CITY |
| BARTOW | ST. PETERSBURG CLEARWATER |
| CLEARWATER EXECUTIVE | |
| HERNANDO COUNTY | TAMPA DOWNS |
| LAKE LAWP | VANDENBERG |
| PETER O. KNIGHT | ZYPHER HILLS MUNI |

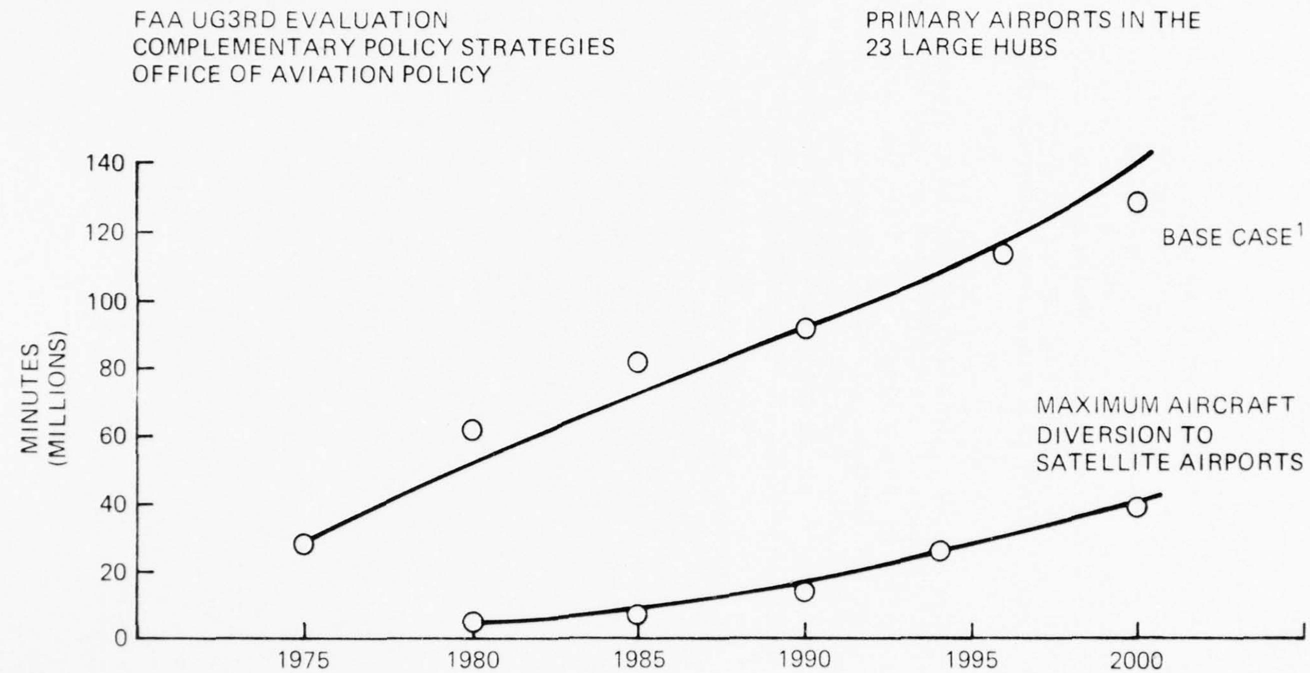
**NEW ORLEANS HUB**

| | |
|---|---|
| LAKE FRONT | WESTWEGO |
| SLYDELL | |

**KANSAS CITY HUB**

| | |
|---|---|
| EAST KANSAS CITY | KANSAS CITY MUNI |
| EXCELSIOR SPRING | KANSAS CITY SUBURBAN |
| FAIRFAX MUNI | McCOMAS |
| GARDNER MUNI | MISSOURI CITY |
| HILLSIDE | MITCHELL |
| INDEPENDENCE MEMORIAL | NOAH'S ARK |
| JOHNSON COUNTY EXEC | RICHARDS GEBAUR AFB |
| JOHNSON COUNTY INDUSTRIAL | ROSCRANTZ MEMORIAL |
| | SHERMAN AAF |

FIGURE 4.5
ANNUAL AIRCRAFT DELAY AT PRIMARY
LARGE HUB AIRPORTS




[1] ASSUMING FAA TERMINAL AREA FORECASTS, NO DIVERSION TO SATELLITE AIRPORT

### 4.2.2 Discussion of Results

This report examined a finite set of constraints to expanded use of satellite airports. Based on the evaluation of these constraints, it is concluded that satellite airports have the potential for relieving a significant amount of air carrier delay at the primary large hub airports. As Figure 4.5 indicates, maximum utilization of the 375 satellite facilities identified in this section could maintain air carrier congestion at or below 1975 levels for up to 15 years, postponing perhaps, the requirement for capacity improvements at some major airports.

With only one exception, each large hub area appears to have ample satellite capacity to absorb most of the general aviation activity currently at the primary air carrier airport. This finding may bear on future policies focusing on general aviation. At Honolulu, the one exception, no immediate opportunity for any significant satellite airport utilization by either commercial or general aviation users is evident.

While there are generally ample facilities for additional general aviation type traffic, few of the satellite airports studied have potential to absorb additional flights of large jets (707 type and larger). In the Northeast, for example, only four airfields (aside from the primary air carrier airports) can handle these larger aircraft. By 1980, it is possible that an additional eight airports could expand sufficiently to accept the bigger jets. These numbers are small considering the Northeast area covers approximately one fourth of the 48 contiguous states. Other regional areas are similarly constrained. It points to the fact that satellite airport development will be necessarily limited for the largest aircraft, with the greatest satellite prospects indicated for propeller-driven and smaller turbine airplanes.

It is important to note that the findings of this section do not constitute an action plan for air traffic diversion; nor are they a forecast. Figure 4.5 represents only the potential for airport congestion relief. While capacity is available at satellite facilities, there are insufficient incentives at present for air traffic to use these airports. Without additional motivation, large scale diversion to satellite airports is unlikely.

### 4.3 Policies Focusing Upon General Aviation

Air carrier airport congestion and delay will be influenced by the level of general aviation growth experienced at major air carrier airports. At present, general aviation activity at the large commercial airports as a percentage of total airport traffic ranges from under 10 percent at O'Hare and Dallas-Ft. Worth to almost 50 percent at Denver and Las Vegas. 19/ FAA forecasts through the year 2000, however, indicate that a significant reduction in general aviation activity at the primary large hub airports can be anticipated. If so, airport runway delays attributable to general aviation will decrease.

In addition to possible impact on airport delay, general aviation activity inside the terminal area has been cited as a potential airspace capacity problem. Here again, the magnitude of the problem is a function of general aviation activity and growth rates. In order to facilitate the control of aircraft operating within the terminal area, an increase in size and number of Terminal Control Areas (TCA's) surrounding major hubs has been proposed. 20/

The TCA is an air traffic management device developed and implemented during the current decade. The first (Atlanta, Georgia) was established in June of 1970 and has been followed successively by 20 additional TCA's. Each TCA can be defined as a prescribed volume of airspace centered on a primary airport(s) serving a metropolitan area and contained within the airspace delegated to an approach control facility for IFR control.

The typical airspace assignment for a TCA is portrayed in Figure 4.6. Within the TCA, specified aircraft avionics equipment requirements must be met by aircraft desiring to use the airspace. In addition, certain pilot qualifications, procedures, and flight restrictions are imposed upon airspace

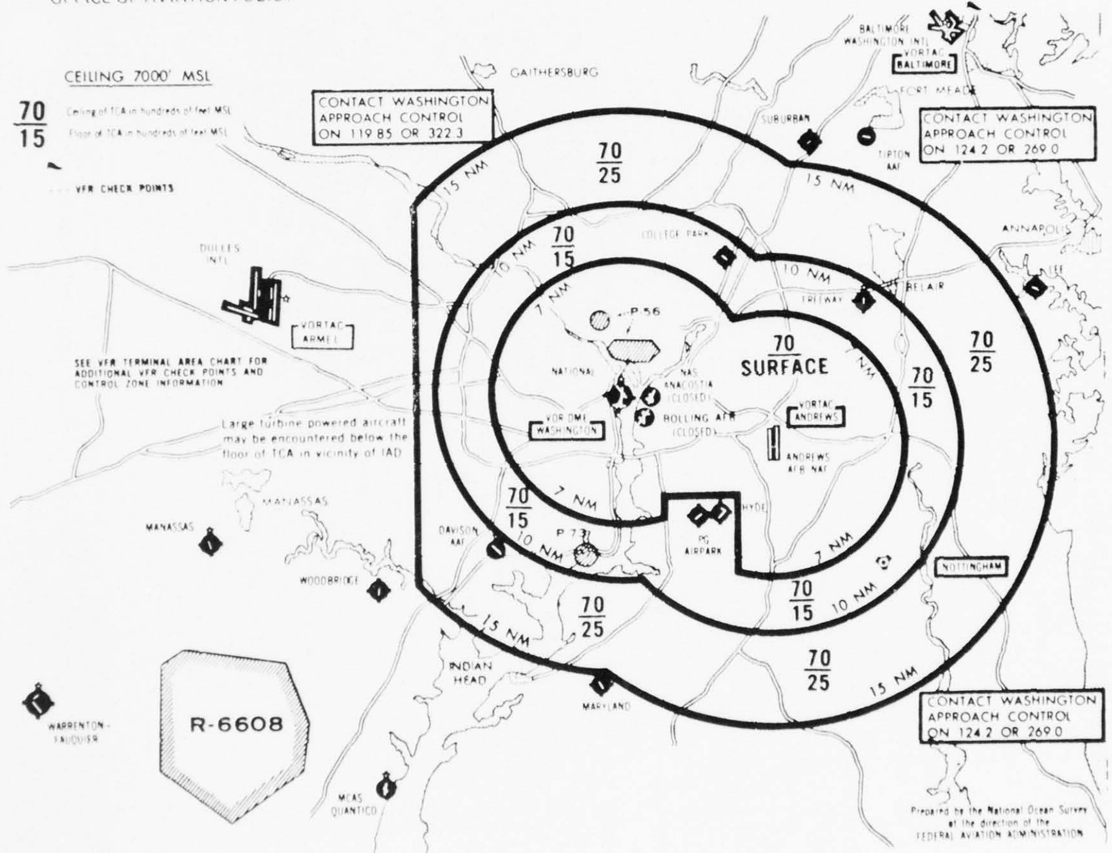
19/ FAA Air Traffic Activity, CY 1974, Department of Transportation, Federal Aviation Administration, March 1975, page 34, [81].

20/ A Review of the Upgraded Third Generation Air Traffic Control System, Department of Transportation, Office of the Secretary of Transportation, August 1974, pages 5-35, [99].

FIGURE 4.6
TCA AIRSPACE ASSIGNMENTS

FAA UG3RD EVALUATION
COMPLEMENTARY POLICY STRATEGIES
OFFICE OF AVIATION POLICY

WASHINGTON TERMINAL CONTROL AREA
AIRMAN'S INFORMATION MANUAL
JANUARY, 1976



users. Specific requirements vary between the two classes of TCA established, either Group I or Group II TCA. Group I TCA's impose the most stringent requirements, as shown in Table 4.7. The requirements of Group I and Group II TCA's are intended to facilitate the safe, orderly flow of air traffic.

The purpose of this section is to explore the potential impacts of TCA restrictions on general aviation activity within terminal control areas. The analysis was undertaken by the General Aviation Operations Research Corporation in order to accomplish the following tasks:

1. Examine the impact on general aviation of selected TCA implementation.

2. Predict the impact on general aviation activity of new TCA's, or, in cases where Terminal Control Areas are already established, expanded TCA's.

An earlier section of this chapter dealt with the impact of peak-time pricing and administrative policy options on general aviation air traffic growth and resultant airport system delays. Refer to Section 4.1 for a discussion of these results.

### 4.3.1 Analytical Approach

The overall strategy applied in the evaluation of TCA impacts consisted of a comparison of general aviation user population profiles at airports with TCA's to airports without TCA's on the assumption that the latter type is typical of the before TCA condition and the former is typical of the after TCA condition at various states of maturity. The analysis proceeded in the following stages:

1. Establish the general aviation user profiles for airports with Group I TCA's, airports with Group II TCA's, and airports without TCA's.

2. Develop a time series comparison of general aviation primary airport operations for the three different types of TCA airports.

3. Develop user profiles and time series comparisons of secondary and overflight operations in terminal area airspace for each of the three types.

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POLICY ANALYSIS OF THE UPGRADED THIRD GENERATION AIR TRAFFIC CO--ETC(U)
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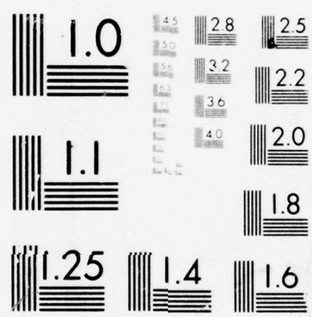


MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-

TABLE 4.7

**TERMINAL CONTROL AREA (TCA) REQUIREMENTS**

FAA UG3RD EVALUATION
COMPLEMENTARY POLICY STRATEGIES
OFFICE OF AVIATION POLICY

| | GROUP I | GROUP II |
|---|---|---|
| PILOT | PRIVATE PILOT'S LICENSE OR BETTER FOR TAKEOFF OR LANDING AT AIRPORTS WITHIN THE TCA. | NO SPECIAL REQUIREMENTS |
| EQUIPMENT | ADEQUATE COMMUNICATIONS FREQUENCIES TO COMMUNICATE WITH CONTROLLING AGENCIES. TRANSPONDER WITH 4096 CODES PLUS ALTITUDE REPORTING CAPABILITY. VOR/TACAN RECEIVER APPROPRIATE TO GROUND FACILITIES. | ADEQUATE COMMUNICATIONS FREQUENCIES TO COMMUNICATE WITH CONTROLLING AGENCIES. TRANSPONDER WITH 4096 CODES FOR OPERATIONS TO AND FROM AIRPORTS WITHIN THE TCA. VOR/TACAN RECEIVER APPROPRIATE TO GROUND FACILITIES. |
| OPERATING RULES | TWO-WAY RADIO CONTACT WITH ATC FACILITY AND CLEARANCE REQUIRED FOR ALL FIXED-WING AIRCRAFT. LARGE TURBINE POWERED AIRCRAFT MUST OPERATE ABOVE FLOOR OF TCA. | TWO-WAY RADIO CONTACT WITH ATC FACILITY AND CLEARANCE REQUIRED FOR ALL FIXED-WING AIRCRAFT. LARGE TURBINE POWERED AIRCRAFT MUST OPERATE ABOVE FLOOR OF TCA. |

4. Integrate results obtained from the first three goals and describe and predict the effects of expansion at existing TCA sites or extension of TCA's to other large hubs.

On-site surveys of six large hub air carrier airports (Los Angeles and San Francisco, Group I TCA's; Seattle and Las Vegas, Group II TCA's; Phoenix and San Diego, non-TCA's) were conducted to establish general aviation user profiles. Data obtained through each of these 24-hour surveys was stratified into the following categories:

- Single engine (3 seats or less)
- Single engine (more than 3 seats)
- Multi-engine piston
- Multi-engine turboprop
- Multi-engine turbojet
- Helicopter

In addition to the real-time survey, a 24-hour data sample was taken from the IFR data strips maintained by the tower personnel at each TCA location. This information augmented the real-time tower counts and provided data on secondary and overflight operations.

Historical data on general aviation operations for time series analysis was compiled for the five-year period 1970 through 1974. Using available data references, baseline trends for general aviation operations at all FAA towered airports were developed as shown in Table 4.8. At each airport surveyed in the study, similar statistics were collected, as shown in Table 4.9. The method of analysis consisted of a comparison of the trends in operations at each of the sample airports to the baseline trend average for all FAA towered airports.

As Table 4.8 suggests, the sum of general aviation plus air taxi operation at towered airports has been relatively constant over the five-year period. Moreover, there are no major changes in numbers of operations at each sample airport coincident with the establishment of TCA's. Generally, a small drop in operation subsequent to TCA establishment was observed. This drop was followed by a gradual recovery to a level of activity consistent with the national trend. Similar evaluations were undertaken with overflight and secondary aircraft operations.

## TABLE 4.8

## GENERAL AVIATION AIRPORT OPERATIONS, ALL AIRPORTS[1]

FAA UG3RD EVALUATION
COMPLEMENTARY POLICY STRATEGIES
OFFICE OF AVIATION POLICY

| | 1970 | 1971 | 1972 | 1973 | 1974 |
|---|---|---|---|---|---|
| TOTAL GENERAL AVIATION[2] | 41384006 | 40400593 | 38171922 | 41363042 | 43123407 |
| TOTAL AIR TAXI[3] | | | 2042068 | 2227945 | 2582218 |
| NUMBER FAA TOWERS[4] | 331 | 343 | 348 | 362 | 394 |
| AVERAGE GENERAL AVIATION | 125027 | 117786 | 109689 | 114262 | 109450 |
| AVERAGE AIR TAXI | | | 5868 | 6154 | 6554 |

1 Three publications constituted the source of this historical general aviation operational data. These included:

1. Aviation Forecasts, Fiscal Years 1975-1986
2. Census of U.S. Civil Aircraft
3. FAA Air Traffic Activity

2 The sum of local plus itinerant operations by calendar year.

3 By calendar year. Prior to 1972 air taxi operations were counted as general aviation.

4 By fiscal year.

## TABLE 4.9
## GENERAL AVIATION AIRPORT OPERATIONS, SAMPLE AIRPORTS

FAA UG3RD EVALUATION
COMPLEMENTARY POLICY STRATEGIES
OFFICE OF AVIATION POLICY

| | 1970 | 1971 | 1972 | 1973 | 1974 |
|---|---|---|---|---|---|
| LOS ANGELES | | | | | |
| GENERAL AVIATION[1] | 119941 | 111832 | 56055 | 58086 | 56467 |
| AIR TAXI[2] | | | 50284 | 50787 | 57711 |
| SAN FRANCISCO | | | | | |
| GENERAL AVIATION[1] | 74121 | 74496 | 49554 | 42234 | 42271 |
| AIR TAXI[2] | | | 12371 | 11714 | 18100 |
| SEATTLE-TACOMA | | | | | |
| GENERAL AVIATION[1] | 45095 | 39089 | 23660 | 21376 | 21492 |
| AIR TAXI[2] | | | 17028 | 19368 | 31654 |
| LAS VEGAS | | | | | |
| GENERAL AVIATION[1] | 119336 | 100579 | 94101 | 115851 | 152044 |
| AIR TAXI[2] | | | 4435 | 2749 | 16741 |
| SAN DIEGO | | | | | |
| GENERAL AVIATION[1] | 125713 | 115914 | 105908 | 102082 | 104449 |
| AIR TAXI[2] | | | 6837 | 7292 | 8828 |
| PHOENIX SKY HARBOR | | | | | |
| GENERAL AVIATION[1] | 258193 | 265810 | 265810 | 274156 | 312682 |
| AIR TAXI[2] | | | 6644 | 7742 | 9010 |

[1] *The sum of local plus itinerant operations by calendar year.*

[2] By calendar year. Prior to 1972 air taxi operations were counted as general aviation.

### 4.3.2 Discussion of Results

Five years of experience with the TCA concept indicates that TCA's are an effective way of providing safe separation among aircraft in terminal areas. This analysis found that TCA's impact general aviation in the following manner:

1. The establishment of a TCA (either Group I or Group II) has little noticeable affect on the total number of airport operations attributable to general aviation aircraft. 21/ There are other factors at work which may have more of an impact on general aviation activity than TCA restrictions. 22/ However, the presence of a TCA is accompanied by a marked shift in the type of general aviation aircraft using the primary TCA airport. This shift is towards the more sophisticated, more expensive, primarily business-orientated aircraft. 23/

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21/ At the Terminal Control Areas evaluated, a rise in business/corporate aircraft activity sufficiently offsets the diversion from TCA primary airports of instructional and personal use aircraft.

22/ It is possible that actions taken by local airport authorities which increase or decrease the amount of ground services for general aviation have affected the level of general aviation operations more than have TCA's.

23/ It appears the TCA establishes an ATC environment which attracts aircraft in the business/executive category. It should be noted that aircraft of this type tend to be compatible with air carrier aircraft; thus, are easier to work into the flow of traffic at these TCA airports. This may tend to reduce congestion and improve safety even though the number of operations are not affected.

2. Overflight and secondary operations, traffic either transiting the TCA or operating from outlying airports under the TCA umbrella, are not obviously affected by the presence or absence of a TCA. This finding is attributed to the fact that the TCA environment does not really constrain those operations. For example, overflight operations can be conducted either IFR or VFR, at user's option. There is no compelling reason, in other words, to switch the IFR for overflights. Similarly, with VFR approaches available for secondary airports beneath the TCA airspace, there is no obvious reason for shifting secondary operations to IFR even though TCA procedures for VFR overflights (usually over the top) and VFR secondary airport operations are perhaps inconvenient, they are still evidently preferable to IFR procedures for many operators.

3. This analysis finds that an extension of TCA airspace down to the surface, encompassing outlying airports, might reduce general aviation terminal activity up to 10 percent. 24/ At the same time, however, it may induce additional upgrading from VFR to IFR operations and add substantially to the ATC system workload--this at a time when the system is already showing signs of strain due to existing traffic levels.

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24/ On the basis of the analytical results, it appears that the TCA environment attracts certain kinds of general aviation traffic. Moreover, there is some upgrading of VFR to IFR by other general aviation operators--an upgrading that probably reflects the operators perception of the relative inconvenience associated with following more complicated VFR procedures versus following TCA IFR procedures. The net effect seems to be that, to date, total terminal area activity (VFR plus IFR) may have been reduced somewhat, but, at the price of increased IFR activity.

Since this pattern has evolved in a system that provides alternatives for VFR traffic around, over and under the TCA's, it is concluded that regulatory actions such as expanding the TCA down to ground level around additional airports, eliminating VFR alternatives, may depress general aviation terminal area traffic levels. The estimate of 10 percent reduction in traffic is based upon the price elasticities of demand for general aviation provided in the Battelle-Columbus General Aviation Cost Impact Study, Vol. I, June 1973, [5].

## 5.0 Findings and Conclusions

This chapter summarizes major results of research on the benefits and costs of the UG3RD from a system perspective and reviews the feasibility of policy actions to complement the UG3RD. Findings and conclusions are presented in two separate sections.

### 5.1 Costs and Benefits of the UG3RD from a Systems Perspective

The alternative UG3RD configurations investigated in the present study, when compared with a scenario of no new action, provide benefits significantly in excess of costs. Benefit-cost ratios range between 10:1 and 19:1 assuming a high level of airline quality DABS/IPC avionics in the fleet. The ratios increase to between 17:1 and 22:1 if DABS/IPC avionics is assumed to be preponderantly composed of standard and medium quality equipment. The system having the largest present value of net benefits is one composed of automated WVAS, advanced metering and spacing, conflict resolution and control message automation, and DABS (Configuration 3). Further, the introduction of IPC (Configurations 4 and 5) produces substantial improvements in aviation safety through the prevention of mid-air collisions and collisions with the terrain.

In all alternatives analyzed, reduction of aircraft and passenger delay produced the largest benefit values. The values associated with delay reduction were at least five times as great as all other types of benefits combined. Estimates of the present value of FAA staff savings exceeded $1 billion in all cases and were equal to or larger than the present value of the costs of implementing alternative UG3RD Configurations 1 through 3. Safety benefits are associated with all UG3RD systems investigated, but in the simpler systems (Configurations 1 through 3), safety benefits are limited to provision of backup accident prevention capability to ATC safety features already in existence or which are presently being implemented. The introduction of IPC will, however, for Configurations 4 and 5, provide significant new accident prevention impacts.

The present discounted value of UG3RD costs range from $391 million for Configuration 1 to $1.6 billion for Configuration 5. For Configurations 2 through 5, user costs constitute significant proportions of the total--at least 30 percent.

## 5.2 Projected Impacts of Complementary Policy Strategies

One of the activities undertaken in this analysis was an evaluation of certain noncapital or relatively low capital policy strategies which might complement the technical features of the UG3RD. The first strategy examined was the use of pricing and administrative alternatives such as peak pricing and quotas, to discourage peak hour airport use. At the majority of air carrier airports most of the delay problem is experienced during these peak traffic periods. This analysis finds that while a schedule of peak pricing and quotas would not transform the daily distribution of flights into a perfectly rectangular pattern, it could effectively smooth the peaks, spreading traffic more uniformly to off-peak hours. This redistribution of traffic can significantly reduce congestion and delay throughout the airport system.

Among alternative airport development options examined in this report, it is concluded that air carrier delays would be minimized in a system incorporating both UG3RD capacity improvements and a peak-load pricing schedule. Comparing capital and noncapital development alternatives, the analysis indicates that, peak pricing and quotas at the top 25 commercial airports would reduce air carrier delays more than hardware features of the UG3RD.

There are economic and institutional constraints, however, limiting the implementation of these policy strategies on a widespread scale. For example, the optimum fare schedule necessary to shift air carrier traffic away from peak demand periods is not presently known. Nor have all the possible issues which might confront the FAA, airport sponsors and the airline been satisfactorily resolved. Perhaps more importantly, a peak pricing strategy would represent a departure from the traditional concept of free access to aviation facilities and would probably generate formidable opposition. The pricing and administrative alternatives reviewed in this report may emerge as more realistic options for the national airspace system when these constraints are overcome.

The second policy option examined in this report was the expanded use of satellite airports in major metropolitan areas. This alternative has often been considered as an efficient method of relieving the traffic increasing con-

gestion at primary air terminals. While numerous constraints impose limits on the overall number of potential satellite candidates, this report finds that maximum use of airports which do offer potential could significantly relieve air traffic delay, easing, perhaps, requirements for capacity improvements at some of the major airports.

The best prospects for satellite use were indicated for propeller-driven and smaller turbine airplanes; few facilities studied appeared to have potential to absorb additional flights of large jet traffic. Significant diversions of any traffic to satellite airports are not anticipated, however, without additional incentives drawing (or forcing) traffic from the primary terminals.

Finally, the report evaluated a proposal to expand the use of Terminal Control Areas (TCA) to facilitate traffic control in the airspace surrounding major airports. While the survey undertaken for this report found no evidence that expanding the use of TCA's would have a major impact on the growth of terminal area traffic, five years of experience with the TCA indicates that it is an effective way of providing safe separation of traffic in the terminal area.

## 6.0 Recommendations

- Configurations of the UG3RD air traffic control system consisting of WVAS, automation, and DABS/IPC at terminals and enroute centers should be implemented as soon as possible.

- A coordinated budget and developmental program should be established within the FAA to expedite early implementation of the UG3RD.

- The development of DABS/IPC should continue in order to accrue full-benefits of the UG3RD system.

- Continued emphasis in the engineering and development program should be given to reducing user acquisition costs of DABS/IPC avionics. To the extent that user costs are reduced, the net benefit of the program will increase as will user acceptance.

- Encourage diversion of air traffic from primary hub airports to satellite airports by improving air navigation facilities at satellite airports. This can be accomplished in part by modifying navigation facilities establishment criteria to reflect full system benefits of satellite airport use.

APPENDIX A

TABULATION OF ANNUAL COSTS
AND BENEFITS OF ALTERNATIVE
UG3RD SYSTEMS

TABLE A.1

ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 1

| | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | | | | | | |
| PASSENGER DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 48.0 | 96.0 | 143.9 | 191.9 | 239.9 | 296.6 | 353.3 | 410.0 | 466.7 | 523.4 |
| AIRCRAFT DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 69.9 | 139.8 | 209.7 | 279.6 | 349.5 | 427.8 | 506.0 | 584.2 | 662.4 | 740.6 |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 4.2 | 6.4 | 8.5 | 10.6 | 11.1 | 11.6 | 12.1 | 12.6 | 13.1 |
| TOTAL TERMINAL BENEFITS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 120.0 | 240.0 | 360.0 | 480.0 | 600.0 | 735.5 | 870.9 | 1,006.3 | 1,141.7 | 1,277.1 |
| ENROUTE CENTERS | | | | | | | | | | | | | | | |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 57.9 | 128.6 | 194.1 | 212.0 | 235.0 | 247.7 | 255.4 | 250.3 | 209.4 | 194.1 |
| ACCIDENT REDUCTION SAVINGS | .9 | .9 | 1.0 | 1.1 | 1.1 | 1.2 | 1.3 | 1.3 | 1.4 | 1.4 | 1.5 | 1.5 | 1.6 | 1.6 | 1.7 |
| TOTAL BENEFITS | .9 | .9 | 1.0 | 1.1 | 1.1 | 179.1 | 369.9 | 555.4 | 693.4 | 836.4 | 984.7 | 1,127.8 | 1,258.2 | 1,352.7 | 1,472.9 |
| FEDERAL AVIATION ADMINISTRATION COSTS | | | | | | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | | | | | | |
| WVAS | 2.4 | 4.0 | 3.5 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| T. AUTOMATION | 8.8 | 2.2 | 9.4 | 7.7 | 6.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| E. AUTOMATION | 9.4 | 10.7 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 1.7 | 2.3 | 2.3 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 22.3 | 19.2 | 26.2 | 22.1 | 21.1 | 14.4 | 14.4 | 3.4 | 1.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FACILITIES & EQUIPMENT | | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 4.2 | 3.6 | 4.4 | 3.7 | 3.8 | 4.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| T.AUTOMATION | 29.3 | 2.2 | 10.0 | 10.0 | 10.0 | 9.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| E.AUTOMATION | .8 | 10.0 | 10.0 | 18.0 | 20.0 | 30.0 | 30.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 7.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL F&E COSTS | 37.7 | 12.2 | 24.2 | 31.6 | 34.4 | 43.6 | 33.8 | 4.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | .2 | .5 | .7 | .9 | 1.1 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 |
| T.AUTOMATION | 0.0 | .6 | .7 | .9 | 1.1 | 1.3 | 1.5 | 1.5 | 1.6 | 1.5 | 1.5 | 1.6 | 1.5 | 1.5 | 1.6 |
| E.AUTOMATION | 0.0 | .1 | 2.2 | 3.2 | 6.2 | 9.1 | 13.6 | 17.3 | 15.0 | 13.2 | 11.7 | 10.9 | 10.9 | 10.9 | 10.9 |
| CENTRAL FLOW C. | 0.0 | 1.5 | 1.8 | 2.2 | 2.2 | 1.9 | 2.0 | 2.0 | 2.1 | 2.1 | 2.2 | 2.0 | 1.9 | 1.8 | 1.8 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL O&M COSTS | 0.0 | 2.2 | 4.7 | 6.5 | 10.0 | 13.0 | 18.0 | 21.9 | 20.0 | 18.2 | 16.7 | 15.9 | 15.6 | 15.6 | 15.6 |
| TOTAL FAA COSTS | 60.0 | 33.6 | 55.1 | 60.2 | 65.5 | 71.0 | 66.2 | 29.4 | 21.0 | 19.2 | 16.7 | 15.9 | 15.6 | 15.6 | 15.6 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | | | | | | |
| AVIONICS EQUIP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O & M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL USER COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL COSTS | 60.0 | 33.6 | 55.1 | 60.2 | 65.5 | 71.0 | 66.2 | 29.4 | 21.0 | 19.2 | 16.7 | 15.9 | 15.6 | 15.6 | 15.6 |

TABLE A.1 (cont.)

ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 1

| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | | |
| PASSENGER DELAY | 619.8 | 716.2 | 812.6 | 909.0 | 1,005.4 | 1,154.4 | 1,303.4 | 1,452.4 | 1,601.4 | 1,750.4 | 14,094.7 |
| AIRCRAFT DELAY | 853.2 | 965.8 | 1,078.4 | 1,190.9 | 1,303.5 | 1,444.0 | 1,584.5 | 1,725.1 | 1,866.6 | 2,006.1 | 17,987.6 |
| FAA STAFF SAVINGS | 13.4 | 13.6 | 14.0 | 14.3 | 14.6 | 14.7 | 14.9 | 15.1 | 15.2 | 15.4 | 237.5 |
| TOTAL TERMINAL BENEFITS | 1,486.4 | 1,695.6 | 1,905.0 | 2,114.2 | 2,323.5 | 2,613.1 | 2,902.8 | 3,192.6 | 3,483.2 | 3,771.9 | 32,319.8 |
| ENROUTE CENTERS | | | | | | | | | | | |
| FAA STAFF SAVINGS | 194.1 | 194.1 | 194.1 | 194.1 | 194.1 | 194.1 | 194.1 | 194.1 | 194.1 | 194.1 | 3,925.5 |
| ACCIDENT REDUCTION SAVINGS | 1.8 | 1.8 | 1.9 | 2.0 | 2.0 | 2.1 | 2.2 | 2.2 | 2.3 | 2.4 | 40.2 |
| TOTAL BENEFITS | 1,682.3 | 1,891.5 | 2,101.0 | 2,310.3 | 2,519.6 | 2,809.3 | 3,099.1 | 3,388.9 | 3,679.6 | 3,968.4 | 36,285.5 |
| FEDERAL AVIATION ADMINISTRATION COSTS | | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 21.9 |
| T. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 34.8 |
| E. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 75.1 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.3 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 145.1 |
| FACILITIES & EQUIPMENT | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 23.8 |
| T.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 71.4 |
| E.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 118.8 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.6 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL F&E COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 221.6 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | | |
| WVAS | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 26.3 |
| T.AUTOMATION | 1.5 | 1.5 | 1.6 | 1.5 | 1.5 | 1.6 | 1.5 | 1.5 | 1.6 | 1.5 | 33.7 |
| E.AUTOMATION | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 244.2 |
| CENTRAL FLOW C. | 1.8 | 1.8 | 1.8 | 1.9 | 1.8 | 1.8 | 1.8 | 1.8 | 1.9 | 1.8 | 45.7 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL O&M COSTS | 15.6 | 15.5 | 15.7 | 15.6 | 15.6 | 15.6 | 15.6 | 15.5 | 15.8 | 15.5 | 349.9 |
| TOTAL FAA COSTS | 15.6 | 15.5 | 15.7 | 15.6 | 15.6 | 15.6 | 15.6 | 15.5 | 15.8 | 15.5 | 716.6 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | | |
| AVIONICS EQUIP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O & M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL USER COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL COSTS | 15.6 | 15.5 | 15.7 | 15.6 | 15.6 | 15.6 | 15.6 | 15.5 | 15.8 | 15.5 | 716.6 |

TABLE A.2

ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 2

| | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | | | | | |
| PASSENGER DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 91.7 | 183.5 | 275.2 | 367.0 | 458.7 | 638.4 | 818.1 | 997.7 | 1,177.4 |
| AIRCRAFT DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 132.9 | 265.8 | 398.7 | 531.6 | 664.4 | 912.9 | 1,161.4 | 1,410.0 | 1,658.5 |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 4.2 | 6.4 | 8.5 | 10.6 | 15.0 | 19.4 | 23.9 | 28.3 |
| TOTAL TERMINAL BENEFITS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 226.7 | 453.5 | 680.3 | 907.1 | 1,133.7 | 1,566.3 | 1,998.9 | 2,431.6 | 2,864.2 |
| ENROUTE CENTERS | | | | | | | | | | | | | | |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 61.3 | 135.4 | 204.3 | 217.1 | 235.0 | 247.7 | 255.4 | 250.3 | 233.2 |
| ACCIDENT REDUCTION SAVINGS | .9 | .9 | 1.0 | 1.1 | 1.1 | 1.2 | 1.3 | 1.3 | 1.4 | 1.4 | 1.5 | 1.5 | 1.6 | 1.6 |
| TOTAL BENEFITS | .9 | .9 | 1.0 | 1.1 | 1.1 | 289.2 | 590.2 | 885.9 | 1,125.6 | 1,370.1 | 1,815.5 | 2,255.8 | 2,683.5 | 3,099.0 |
| FEDERAL AVIATION ADMINISTRATION COSTS | | | | | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | | | | | |
| WVAS | 2.4 | 4.0 | 3.5 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| T. AUTOMATION | 8.8 | 2.2 | 9.4 | 7.7 | 6.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| E. AUTOMATION | 9.4 | 10.7 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 1.7 | 2.3 | 2.3 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 10.0 | 8.0 | 5.0 | 1.8 | 1.5 | 1.5 | 1.5 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 32.3 | 27.2 | 31.2 | 23.9 | 22.6 | 15.9 | 15.9 | 15.9 | 12.0 | 12.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FACILITIES & EQUIPMENT | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 4.2 | 3.6 | 4.4 | 3.7 | 3.8 | 4.1 | 0.0 | 0.0 | .2 | .2 | .2 | .3 |
| T.AUTOMATION | 29.3 | 2.2 | 10.0 | 10.0 | 10.0 | 9.9 | 4.9 | 4.9 | 4.9 | 4.8 | 12.8 | 12.7 | 0.0 | 0.0 |
| E.AUTOMATION | .8 | 10.0 | 10.0 | 18.0 | 20.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 7.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.4 | 14.5 | 18.8 | 23.5 | 12.3 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL F&E COSTS | 37.7 | 12.2 | 24.2 | 31.6 | 34.4 | 43.6 | 38.7 | 39.0 | 45.3 | 49.3 | 31.8 | 36.4 | 12.5 | .3 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | .2 | .5 | .7 | .9 | 1.1 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 |
| T.AUTOMATION | 0.0 | .6 | .7 | .9 | 1.1 | 1.3 | 1.5 | 1.6 | 1.7 | 1.9 | 2.0 | 2.2 | 2.5 | 2.5 |
| E.AUTOMATION | 0.0 | .1 | 2.1 | 3.2 | 6.2 | 9.1 | 13.6 | 17.3 | 20.3 | 23.1 | 25.7 | 23.3 | 21.6 | 20.5 |
| CENTRAL FLOW C. | 0.0 | 1.5 | 1.8 | 2.2 | 2.2 | 1.9 | 2.0 | 2.0 | 2.1 | 2.1 | 2.2 | 2.0 | 1.9 | 1.8 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .4 | 1.3 | 2.2 | 3.6 | 4.5 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL O&M COSTS | 0.0 | 2.2 | 4.6 | 6.5 | 10.0 | 13.0 | 18.0 | 22.0 | 25.4 | 28.9 | 32.5 | 31.1 | 30.9 | 30.7 |
| TOTAL FAA COSTS | 70.0 | 41.6 | 60.0 | 62.0 | 67.0 | 72.5 | 72.6 | 76.9 | 82.7 | 90.2 | 64.3 | 67.5 | 43.4 | 31.0 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | | | | | |
| AVIONICS EQUIP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 165.3 | 170.4 | 170.5 | 170.6 | 168.7 |
| O & M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 23.1 | 28.0 | 34.0 | 38.8 |
| TOTAL USER COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 165.3 | 193.5 | 198.5 | 204.6 | 207.5 |
| TOTAL COSTS | 70.0 | 41.6 | 60.0 | 62.0 | 67.0 | 72.5 | 72.6 | 76.9 | 82.7 | 255.5 | 257.8 | 266.0 | 248.0 | 238.5 |

TABLE A.2 (cont.)

ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 2

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | | | |
| PASSENGER DELAY | 1,357.1 | 1,600.6 | 1,844.1 | 2,087.6 | 2,331.2 | 2,574.7 | 2,926.7 | 3,278.6 | 3,630.6 | 3,982.5 | 4,334.5 | 34,955.9 |
| AIRCRAFT DELAY | 1,907.0 | 2,216.2 | 2,525.4 | 2,834.6 | 3,143.8 | 3,453.1 | 3,839.2 | 4,225.3 | 4,611.5 | 4,997.6 | 5,383.7 | 46,273.6 |
| FAA STAFF SAVINGS | 32.7 | 33.2 | 33.8 | 34.3 | 34.9 | 35.4 | 35.8 | 36.3 | 36.7 | 37.1 | 37.5 | 506.1 |
| TOTAL TERMINAL BENEFITS | 3,296.8 | 3,850.0 | 4,403.3 | 4,956.5 | 5,509.9 | 6,063.2 | 6,801.7 | 7,540.2 | 8,278.8 | 9,017.2 | 9,755.7 | 81,735.6 |
| ENROUTE CENTERS | | | | | | | | | | | | |
| FAA STAFF SAVINGS | 233.3 | 230.7 | 228.2 | 224.7 | 221.3 | 217.9 | 212.8 | 207.7 | 203.5 | 200.1 | 196.7 | 4,216.6 |
| ACCIDENT REDUCTION SAVINGS | 1.7 | 1.8 | 1.8 | 1.9 | 2.0 | 2.0 | 2.1 | 2.2 | 2.2 | 2.3 | 2.4 | 40.2 |
| TOTAL BENEFITS | 3,531.8 | 4,082.5 | 4,633.3 | 5,183.1 | 5,733.2 | 6,283.1 | 7,016.6 | 7,750.1 | 8,484.5 | 9,219.6 | 9,954.8 | 85,992.4 |
| FEDERAL AVIATION ADMINISTRATION COSTS | | | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 21.9 |
| T. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 34.8 |
| E. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 108.1 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.3 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 30.8 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 208.9 |
| FACILITIES & EQUIPMENT | | | | | | | | | | | | |
| WVAS | .3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 25.0 |
| T.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 116.4 |
| E.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 208.8 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.6 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 79.5 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL F&E COSTS | .3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 437.3 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | | | |
| WVAS | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 26.3 |
| T.AUTOMATION | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 48.0 |
| E.AUTOMATION | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 405.0 |
| CENTRAL FLOW C. | 1.8 | 1.8 | 1.8 | 1.8 | 1.9 | 1.8 | 1.8 | 1.8 | 1.8 | 1.9 | 1.8 | 45.7 |
| DABS | 4.5 | 4.5 | 4.4 | 4.5 | 4.5 | 4.6 | 4.5 | 4.4 | 4.5 | 4.5 | 4.4 | 61.3 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL O&M COSTS | 30.0 | 30.1 | 29.9 | 30.1 | 30.1 | 30.2 | 30.0 | 30.0 | 30.0 | 30.2 | 29.9 | 586.3 |
| TOTAL FAA COSTS | 30.3 | 30.1 | 29.9 | 30.1 | 30.1 | 30.2 | 30.0 | 30.0 | 30.0 | 30.2 | 29.9 | 1,232.5 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | | | |
| AVIONICS EQUIP | 13.8 | 15.4 | 22.0 | 20.3 | 20.5 | 81.5 | 89.5 | 98.5 | 96.7 | 115.9 | 131.2 | 1,550.8 |
| O & M | 43.6 | 55.6 | 67.0 | 78.1 | 88.7 | 89.3 | 100.6 | 105.0 | 109.5 | 113.9 | 119.3 | 1,094.5 |
| TOTAL USER COSTS | 57.4 | 71.0 | 89.0 | 98.4 | 109.2 | 170.8 | 190.1 | 203.5 | 206.2 | 229.8 | 250.5 | 2,645.3 |
| TOTAL COSTS | 87.7 | 101.1 | 118.9 | 128.5 | 139.3 | 201.0 | 220.1 | 233.5 | 236.2 | 260.0 | 280.4 | 3,877.8 |

TABLE A.3

ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 3

| | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | | | | | |
| PASSENGER DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 91.7 | 183.5 | 275.2 | 367.0 | 458.7 | 638.4 | 818.1 | 997.7 | 1,177.4 |
| AIRCRAFT DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 132.9 | 265.8 | 398.7 | 531.6 | 664.4 | 912.9 | 1,161.4 | 1,410.0 | 1,658.5 |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 4.2 | 6.4 | 8.5 | 10.6 | 15.0 | 19.4 | 23.9 | 28.3 |
| TOTAL TERMINAL BENEFITS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 226.7 | 453.5 | 680.3 | 907.1 | 1,133.7 | 1,566.3 | 1,998.9 | 2,431.6 | 2,864.2 |
| ENROUTE CENTERS | | | | | | | | | | | | | | |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 61.3 | 135.4 | 204.3 | 217.1 | 235.0 | 247.7 | 255.4 | 250.3 | 280.9 |
| ACCIDENT REDUCTION | | | | | | | | | | | | | | |
| SAVINGS | .9 | .9 | 1.0 | 1.1 | 1.1 | 1.2 | 1.3 | 1.3 | 1.4 | 1.4 | 1.5 | 1.5 | 1.6 | 1.6 |
| TOTAL BENEFITS | .9 | .9 | 1.0 | 1.1 | 1.1 | 289.2 | 590.2 | 885.9 | 1,125.6 | 1,370.1 | 1,815.5 | 2,255.8 | 2,683.5 | 3,146.7 |
| FEDERAL AVIATION ADMINISTRATION COSTS | | | | | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | | | | | |
| WVAS | 2.4 | 4.0 | 3.5 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| T. AUTOMATION | 8.8 | 2.2 | 9.4 | 7.7 | 6.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| E. AUTOMATION | 9.4 | 10.7 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 1.7 | 2.3 | 2.3 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 10.0 | 8.0 | 5.0 | 1.8 | 1.5 | 1.5 | 1.5 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 32.3 | 27.2 | 31.2 | 23.9 | 22.6 | 15.9 | 15.9 | 15.9 | 12.0 | 12.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FACILITIES & EQUIPMENT | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 4.2 | 3.6 | 4.4 | 3.7 | 3.8 | 4.1 | 0.0 | 0.0 | .2 | .2 | .2 | .3 |
| T.AUTOMATION | 29.3 | 2.2 | 10.0 | 10.0 | 10.0 | 9.9 | 4.9 | 4.9 | 4.9 | 4.9 | 12.8 | 12.7 | 0.0 | 0.0 |
| E.AUTOMATION | .8 | 10.0 | 10.0 | 18.0 | 20.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 7.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 15.5 | 28.2 | 35.3 | 27.5 | 27.5 | 29.4 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL F&E COSTS | 37.7 | 12.2 | 24.2 | 31.6 | 34.4 | 43.6 | 38.7 | 39.0 | 50.4 | 63.1 | 48.3 | 40.4 | 27.7 | 29.7 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | .2 | .5 | .7 | .9 | 1.1 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 |
| T.AUTOMATION | 0.0 | .6 | .7 | .9 | 1.1 | 1.3 | 1.5 | 1.6 | 1.7 | 1.9 | 2.0 | 2.2 | 2.5 | 2.5 |
| E.AUTOMATION | 0.0 | .1 | 2.1 | 3.2 | 6.2 | 9.1 | 13.6 | 17.3 | 20.3 | 23.1 | 25.7 | 23.3 | 21.6 | 20.5 |
| CENTRAL FLOW C. | 0.0 | 1.5 | 1.8 | 2.2 | 2.2 | 1.9 | 2.0 | 2.0 | 2.1 | 2.1 | 2.2 | 2.0 | 1.9 | 1.8 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .7 | 2.2 | 4.5 | 6.8 | 9.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL O&M COSTS | 0.0 | 2.2 | 4.6 | 6.5 | 10.0 | 13.0 | 18.0 | 22.0 | 25.4 | 29.2 | 33.4 | 33.4 | 34.1 | 35.2 |
| TOTAL FAA COSTS | 70.0 | 41.6 | 60.0 | 62.0 | 67.0 | 72.5 | 72.6 | 76.9 | 87.8 | 104.3 | 81.7 | 73.8 | 61.8 | 64.9 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | | | | | |
| AVIONICS EQUIP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 165.3 | 170.4 | 170.5 | 170.6 | 168.7 |
| O & M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 23.1 | 28.0 | 34.0 | 38.8 |
| TOTAL USER COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 165.3 | 193.5 | 198.5 | 204.6 | 207.5 |
| TOTAL COSTS | 70.0 | 41.6 | 60.0 | 62.0 | 67.0 | 72.5 | 72.6 | 76.9 | 87.8 | 269.6 | 275.2 | 272.3 | 266.4 | 272.4 |

TABLE A.3 (cont.)

ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 3

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | | | |
| PASSENGER DELAY | 1,357.1 | 1,600.6 | 1,844.1 | 2,087.6 | 2,331.2 | 2,574.7 | 2,926.7 | 3,278.6 | 3,630.6 | 3,982.5 | 4,334.5 | 34,955.9 |
| AIRCRAFT DELAY | 1,907.0 | 2,216.2 | 2,525.4 | 2,834.6 | 3,143.8 | 3,453.1 | 3,839.2 | 4,225.3 | 4,611.5 | 4,997.6 | 5,383.7 | 46,273.6 |
| FAA STAFF SAVINGS | 32.7 | 33.2 | 33.8 | 34.3 | 34.9 | 35.4 | 35.8 | 36.3 | 36.7 | 37.1 | 37.5 | 506.1 |
| TOTAL TERMINAL BENEFITS | 3,296.8 | 3,850.0 | 4,403.3 | 4,956.5 | 5,509.9 | 6,063.2 | 6,801.7 | 7,540.2 | 8,278.8 | 9,017.2 | 9,755.7 | 81,735.6 |
| ENROUTE CENTERS | | | | | | | | | | | | |
| FAA STAFF SAVINGS | 311.6 | 303.9 | 296.3 | 286.0 | 275.8 | 265.6 | 250.3 | 234.9 | 222.2 | 212.0 | 201.9 | 4,747.9 |
| ACCIDENT REDUCTION SAVINGS | 1.7 | 1.8 | 1.8 | 1.9 | 2.0 | 2.0 | 2.1 | 2.2 | 2.2 | 2.3 | 2.4 | 40.2 |
| TOTAL BENEFITS | 3,610.1 | 4,155.7 | 4,701.4 | 5,244.4 | 5,787.7 | 6,330.8 | 7,054.1 | 7,777.3 | 8,503.2 | 9,231.5 | 9,960.0 | 86,523.7 |
| FEDERAL AVIATION ADMINISTRATION COSTS | | | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 21.9 |
| T. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 34.8 |
| E. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 108.1 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.3 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 30.8 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 208.9 |
| FACILITIES & EQUIPMENT | | | | | | | | | | | | |
| WVAS | .3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 25.0 |
| T.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 116.5 |
| E.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 208.8 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.6 |
| DABS | 37.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 200.4 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL F&E COSTS | 37.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 558.3 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | | | |
| WVAS | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 26.3 |
| T.AUTOMATION | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 48.0 |
| E.AUTOMATION | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 405.0 |
| CENTRAL FLOW C. | 1.8 | 1.8 | 1.8 | 1.8 | 1.9 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 45.6 |
| DABS | 11.3 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 169.5 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL O&M COSTS | 36.8 | 39.1 | 39.0 | 39.1 | 39.1 | 39.1 | 39.0 | 39.1 | 39.0 | 39.1 | 39.0 | 694.4 |
| TOTAL FAA COSTS | 74.1 | 39.1 | 39.0 | 39.1 | 39.1 | 39.1 | 39.0 | 39.1 | 39.0 | 39.1 | 39.0 | 1,461.6 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | | | |
| AVIONICS EQUIP | 13.8 | 15.4 | 22.0 | 20.3 | 20.5 | 81.5 | 89.5 | 98.5 | 96.7 | 115.9 | 131.2 | 1,550.8 |
| O & M | 43.6 | 55.6 | 67.0 | 78.1 | 88.7 | 89.3 | 100.6 | 105.0 | 109.5 | 113.9 | 119.3 | 1,094.5 |
| TOTAL USER COSTS | 57.4 | 71.0 | 89.0 | 98.4 | 109.2 | 170.8 | 190.1 | 203.5 | 206.2 | 229.8 | 250.5 | 2,645.3 |
| TOTAL COSTS | 131.5 | 110.1 | 128.0 | 137.5 | 148.3 | 209.9 | 229.1 | 242.6 | 245.2 | 268.9 | 289.5 | 4,106.9 |

TABLE A.4

ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 4

| | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | | | | | |
| PASSENGER DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 91.7 | 183.5 | 275.2 | 367.0 | 458.7 | 638.4 | 818.1 | 997.7 | 1,177.4 |
| AIRCRAFT DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 132.9 | 265.8 | 398.7 | 531.6 | 664.4 | 912.9 | 1,161.4 | 1,410.0 | 1,658.5 |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 4.2 | 6.4 | 8.5 | 10.6 | 15.0 | 19.4 | 23.9 | 28.3 |
| TOTAL TERMINAL BENEFITS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 226.7 | 453.5 | 680.3 | 907.1 | 1,133.7 | 1,566.3 | 1,998.9 | 2,431.6 | 2,864.2 |
| ENROUTE CENTERS | | | | | | | | | | | | | | |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 61.3 | 135.4 | 204.3 | 217.1 | 235.0 | 247.7 | 255.4 | 250.3 | 233.2 |
| ACCIDENT REDUCTION SAVINGS | .9 | .9 | 1.0 | 1.1 | 1.1 | 1.3 | 1.3 | 1.3 | 1.4 | 1.5 | 4.6 | 7.8 | 10.9 | 11.4 |
| TOTAL BENEFITS | .9 | .9 | 1.0 | 1.1 | 1.1 | 289.3 | 590.2 | 885.9 | 1,125.6 | 1,370.2 | 1,818.6 | 2,267.1 | 2,692.8 | 3,108.8 |
| FEDERAL AVIATION ADMINISTRATION COSTS | | | | | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | | | | | |
| WVAS | 2.4 | 4.0 | 3.5 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| T. AUTOMATION | 8.8 | 2.2 | 9.4 | 7.7 | 6.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| F. AUTOMATION | 9.4 | 10.7 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 1.7 | 2.3 | 2.3 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 10.0 | 8.0 | 5.0 | 1.8 | 1.5 | 1.5 | 1.5 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 3.0 | 3.0 | 1.5 | 1.5 | 1.5 | 1.5 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 32.3 | 30.2 | 34.2 | 25.4 | 24.1 | 17.4 | 17.4 | 16.9 | 12.0 | 12.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FACILITIES & EQUIPMENT | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 4.2 | 3.6 | 4.4 | 3.7 | 3.8 | 4.1 | 0.0 | 0.0 | .2 | .2 | .2 | .3 |
| T.AUTOMATION | 29.3 | 2.2 | 10.0 | 10.0 | 10.0 | 9.9 | 4.9 | 4.9 | 4.9 | 4.8 | 12.8 | 12.7 | 0.0 | 0.0 |
| F.AUTOMATION | .8 | 10.0 | 10.0 | 18.0 | 20.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 7.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.4 | 14.5 | 18.8 | 23.5 | 12.3 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.5 | 2.5 | 3.0 | 2.0 | 0.0 |
| TOTAL F&E COSTS | 37.7 | 12.2 | 24.2 | 31.6 | 34.4 | 43.6 | 38.7 | 39.0 | 46.3 | 50.8 | 34.3 | 39.4 | 14.5 | .3 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | .2 | .5 | .7 | .9 | 1.1 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 |
| T.AUTOMATION | 0.0 | .6 | .7 | .9 | 1.1 | 1.3 | 1.5 | 1.6 | 1.7 | 1.9 | 2.0 | 2.2 | 2.5 | 2.5 |
| F.AUTOMATION | 0.0 | .1 | 2.1 | 3.2 | 6.2 | 9.1 | 13.6 | 17.3 | 20.3 | 23.1 | 25.7 | 23.3 | 21.6 | 20.5 |
| CENTRAL FLOW C. | 0.0 | 1.5 | 1.8 | 2.2 | 2.2 | 1.9 | 2.0 | 2.0 | 2.1 | 2.1 | 2.2 | 2.0 | 1.9 | 1.9 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .5 | 1.1 | 2.2 | 3.6 | 4.5 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .2 | .5 | 1.0 | 1.6 | 2.0 |
| TOTAL O&M COSTS | 0.0 | 2.2 | 4.6 | 6.5 | 10.0 | 13.0 | 18.0 | 22.0 | 25.4 | 29.2 | 32.8 | 32.1 | 32.5 | 32.8 |
| TOTAL FAA COSTS | 70.0 | 44.6 | 63.0 | 63.5 | 68.5 | 74.0 | 74.1 | 77.9 | 83.7 | 92.0 | 67.1 | 71.5 | 47.0 | 33.1 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | | | | | |
| AVIONICS EQUIP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 207.9 | 206.0 | 200.8 | 198.4 | 199.8 |
| O & M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 26.9 | 41.4 | 54.9 | 68.1 |
| TOTAL USER COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 207.9 | 232.9 | 242.2 | 253.3 | 267.9 |
| TOTAL COSTS | 70.0 | 44.6 | 63.0 | 63.5 | 68.5 | 74.0 | 74.1 | 77.9 | 83.7 | 299.9 | 300.0 | 313.7 | 300.3 | 301.0 |

TABLE A.4 (cont.)

ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 4

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | | | |
| PASSENGER DELAY | 1,357.1 | 1,600.6 | 1,844.1 | 2,087.6 | 2,331.2 | 2,574.7 | 2,926.7 | 3,278.6 | 3,630.6 | 3,982.5 | 4,334.5 | 34,955.9 |
| AIRCRAFT DELAY | 1,907.0 | 2,216.2 | 2,525.4 | 2,834.6 | 3,143.8 | 3,453.1 | 3,839.2 | 4,225.3 | 4,611.5 | 4,997.6 | 5,383.7 | 46,273.6 |
| FAA STAFF SAVINGS | 32.7 | 33.2 | 33.8 | 34.3 | 34.9 | 35.4 | 35.8 | 36.3 | 36.7 | 37.1 | 37.5 | 506.1 |
| TOTAL TERMINAL BENEFITS | 3,296.8 | 3,850.0 | 4,403.3 | 4,956.5 | 5,509.9 | 6,063.2 | 6,801.7 | 7,540.2 | 8,278.8 | 9,017.2 | 9,755.7 | 81,735.6 |
| ENROUTE CENTERS | | | | | | | | | | | | |
| FAA STAFF SAVINGS | 233.3 | 230.7 | 228.2 | 224.7 | 221.3 | 217.9 | 212.8 | 207.7 | 203.5 | 200.1 | 196.7 | 4,216.6 |
| ACCIDENT REDUCTION SAVINGS | 17.3 | 21.6 | 22.4 | 30.3 | 34.7 | 38.9 | 40.2 | 41.6 | 43.0 | 44.5 | 45.9 | 426.9 |
| TOTAL BENEFITS | 3,547.4 | 4,102.3 | 4,653.9 | 5,211.5 | 5,765.9 | 6,320.0 | 7,054.7 | 7,789.5 | 8,525.3 | 9,261.8 | 9,998.3 | 86,379.1 |
| FEDERAL AVIATION ADMINISTRATION COSTS | | | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 21.9 |
| T. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 34.8 |
| E. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 108.1 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.3 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 30.8 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.0 |
| TOTAL E&D COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 221.9 |
| FACILITIES & EQUIPMENT | | | | | | | | | | | | |
| WVAS | .3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 25.0 |
| T.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 116.4 |
| E.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 208.8 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.6 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 79.5 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.0 |
| TOTAL F&E COSTS | .3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 447.3 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | | | |
| WVAS | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 26.3 |
| T.AUTOMATION | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 48.0 |
| E.AUTOMATION | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 405.0 |
| CENTRAL FLOW C. | 1.8 | 1.8 | 1.8 | 1.8 | 1.9 | 1.8 | 1.8 | 1.8 | 1.8 | 1.9 | 1.8 | 45.8 |
| DABS | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 61.4 |
| IPC | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 27.3 |
| TOTAL O&M COSTS | 32.0 | 32.1 | 32.0 | 32.1 | 32.1 | 32.1 | 32.0 | 32.1 | 32.0 | 32.2 | 32.0 | 613.8 |
| TOTAL FAA COSTS | 32.3 | 32.1 | 32.0 | 32.1 | 32.1 | 32.1 | 32.0 | 32.1 | 32.0 | 32.2 | 32.0 | 1,283.0 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | | | |
| AVIONICS EQUIP | 44.8 | 43.5 | 41.8 | 39.3 | 36.8 | 68.6 | 96.7 | 114.1 | 131.3 | 146.3 | 166.8 | 1,942.9 |
| O & M | 81.2 | 85.4 | 89.1 | 92.4 | 95.3 | 88.1 | 94.2 | 101.1 | 107.4 | 114.7 | 122.0 | 1,262.2 |
| TOTAL USER COSTS | 126.0 | 128.9 | 130.9 | 131.7 | 132.1 | 156.7 | 190.9 | 215.2 | 238.7 | 261.0 | 288.8 | 3,205.1 |
| TOTAL COSTS | 158.3 | 161.0 | 162.9 | 163.8 | 164.2 | 188.8 | 222.9 | 247.3 | 270.7 | 293.2 | 320.8 | 4,488.1 |

TABLE A.5

ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 5

| | 1976 | 19[illegible] | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | | | | | |
| PASSENGER DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 91.7 | 183.5 | 275.2 | 367.0 | 458.7 | 638.4 | 818.1 | 997.7 | 1,177.4 |
| AIRCRAFT DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 132.9 | 265.8 | 398.7 | 531.6 | 664.4 | 912.9 | 1,161.4 | 1,410.0 | 1,658.5 |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 4.2 | 6.4 | 8.5 | 10.6 | 15.0 | 19.4 | 23.9 | 28.3 |
| TOTAL TERMINAL BENEFITS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 226.7 | 453.5 | 680.3 | 907.1 | 1,133.7 | 1,566.3 | 1,998.9 | 2,431.6 | 2,864.2 |
| ENROUTE CENTERS | | | | | | | | | | | | | | |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 61.3 | 135.4 | 204.3 | 217.1 | 235.0 | 247.7 | 255.4 | 250.3 | 280.9 |
| ACCIDENT REDUCTION | | | | | | | | | | | | | | |
| SAVINGS | .9 | .9 | 1.0 | 1.1 | 1.1 | 1.3 | 1.3 | 1.3 | 1.4 | 1.4 | 6.4 | 15.3 | 22.1 | 29.1 |
| | ---- | ---- | ---- | ---- | ---- | ----- | ----- | ----- | ------- | ------- | ------- | ------- | ------- | ------- |
| TOTAL BENEFITS | .9 | .9 | 1.0 | 1.1 | 1.1 | 289.3 | 590.2 | 885.9 | 1,125.6 | 1,370.1 | 1,820.4 | 2,269.6 | 2,704.0 | 3,174.2 |
| FEDERAL AVIATION ADMINISTRATION COSTS | | | | | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | | | | | |
| WVAS | 2.4 | 4.0 | 3.5 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| T. AUTOMATION | 8.8 | 2.2 | 9.4 | 7.7 | 6.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| E. AUTOMATION | 9.4 | 10.7 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 1.7 | 2.3 | 2.3 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 10.0 | 8.0 | 5.0 | 1.8 | 1.5 | 1.5 | 1.5 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 3.0 | 3.0 | 1.5 | 1.5 | 1.5 | 1.5 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 32.3 | 30.2 | 34.2 | 25.4 | 24.1 | 17.4 | 17.4 | 16.9 | 12.0 | 12.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FACILITIES & EQUIPMENT | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 4.2 | 3.6 | 4.4 | 3.7 | 3.8 | 4.1 | 0.0 | 0.0 | .2 | .2 | .2 | .3 |
| T.AUTOMATION | 29.3 | 2.2 | 10.0 | 10.0 | 10.0 | 9.9 | 4.9 | 4.9 | 4.9 | 4.8 | 12.8 | 12.7 | 0.0 | 0.0 |
| E.AUTOMATION | .8 | 10.0 | 10.0 | 18.0 | 20.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 7.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 15.5 | 28.2 | 35.3 | 27.5 | 27.5 | 29.4 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 | 3.5 | 5.0 | 5.0 | 5.0 | 5.0 |
| TOTAL F&E COSTS | 37.7 | 12.2 | 24.2 | 31.6 | 34.4 | 43.6 | 38.7 | 39.0 | 51.9 | 66.5 | 53.3 | 45.4 | 32.7 | 34.7 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | .2 | .5 | .7 | .9 | 1.1 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 |
| T.AUTOMATION | 0.0 | .6 | .7 | .9 | 1.1 | 1.3 | 1.5 | 1.6 | 1.7 | 1.9 | 2.0 | 2.2 | 2.5 | 2.5 |
| E.AUTOMATION | 0.0 | .1 | 2.1 | 3.2 | 6.2 | 9.1 | 13.6 | 17.3 | 20.3 | 23.1 | 25.7 | 23.3 | 21.6 | 20.5 |
| CENTRAL FLOW C. | 0.0 | 1.5 | 1.8 | 2.2 | 2.2 | 1.9 | 2.0 | 2.0 | 2.1 | 2.1 | 2.2 | 2.0 | 1.9 | 1.9 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .7 | 2.3 | 4.5 | 6.8 | 9.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .3 | 1.0 | 2.0 | 3.0 | 4.0 |
| TOTAL O&M COSTS | 0.0 | 2.2 | 4.6 | 6.5 | 10.0 | 13.0 | 18.0 | 22.0 | 25.4 | 29.5 | 34.5 | 35.4 | 37.1 | 39.3 |
| TOTAL FAA COSTS | 70.0 | 44.6 | 63.0 | 63.5 | 68.5 | 74.0 | 74.1 | 77.9 | 89.3 | 108.0 | 87.8 | 80.8 | 69.8 | 74.0 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | | | | | |
| AVIONICS EQUIP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 215.6 | 224.1 | 223.8 | 229.0 | 236.6 |
| O & M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 45.4 | 65.0 | 83.8 | 102.3 |
| TOTAL USER COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 215.6 | 269.5 | 288.8 | 312.8 | 338.9 |
| | ---- | ---- | ---- | ---- | ---- | ----- | ----- | ----- | ------- | ------- | ------- | ------- | ------- | ------- |
| TOTAL COSTS | 70.0 | 44.6 | 63.0 | 63.5 | 68.5 | 74.0 | 74.1 | 77.9 | 89.3 | 323.6 | 357.3 | 369.6 | 382.6 | 412.9 |

TABLE A.5 (cont.)

ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 5

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | | | |
| PASSENGER DELAY | 1,357.1 | 1,600.6 | 1,844.1 | 2,087.6 | 2,331.2 | 2,574.7 | 2,926.7 | 3,278.6 | 3,630.6 | 3,982.5 | 4,334.5 | 34,955.9 |
| AIRCRAFT DELAY | 1,907.0 | 2,216.2 | 2,525.4 | 2,834.6 | 3,143.8 | 3,453.1 | 3,839.2 | 4,225.3 | 4,611.5 | 4,997.6 | 5,383.7 | 46,273.6 |
| FAA STAFF SAVINGS | 32.7 | 33.2 | 33.8 | 34.3 | 34.9 | 35.4 | 35.8 | 36.3 | 36.7 | 37.1 | 37.5 | 506.1 |
| TOTAL TERMINAL BENEFITS | 3,296.8 | 3,850.0 | 4,403.3 | 4,956.5 | 5,509.9 | 6,063.2 | 6,801.7 | 7,540.2 | 8,278.8 | 9,017.2 | 9,755.7 | 81,735.6 |
| ENROUTE CENTERS | | | | | | | | | | | | |
| FAA STAFF SAVINGS | 311.6 | 303.9 | 296.3 | 286.0 | 275.8 | 265.6 | 250.3 | 234.9 | 222.2 | 212.0 | 201.9 | 4,747.9 |
| ACCIDENT REDUCTION SAVINGS | 36.1 | 46.6 | 57.3 | 67.9 | 78.4 | 89.1 | 92.3 | 95.4 | 98.6 | 101.9 | 105.1 | 953.3 |
| TOTAL BENEFITS | 3,644.5 | 4,200.5 | 4,756.9 | 5,310.4 | 5,864.1 | 6,417.9 | 7,144.3 | 7,870.5 | 8,599.6 | 9,331.1 | 10,062.7 | 87,436.8 |
| FEDERAL AVIATION ADMINISTRATION COSTS | | | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 21.9 |
| T. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 34.8 |
| E. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 108.1 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.3 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 30.8 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.0 |
| TOTAL E&D COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 221.9 |
| FACILITIES & EQUIPMENT | | | | | | | | | | | | |
| WVAS | .3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 25.0 |
| T.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 116.4 |
| E.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 208.8 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.6 |
| DABS | 37.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 200.4 |
| IPC | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 30.0 |
| TOTAL F&E COSTS | 42.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 588.2 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | | | |
| WVAS | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 | 26.3 |
| T.AUTOMATION | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 48.0 |
| E.AUTOMATION | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 405.0 |
| CENTRAL FLOW C. | 1.8 | 1.8 | 1.8 | 1.8 | 1.9 | 1.8 | 1.8 | 1.8 | 1.8 | 1.9 | 1.8 | 45.8 |
| DABS | 11.3 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 169.6 |
| IPC | 5.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 75.3 |
| TOTAL O&M COSTS | 41.8 | 45.1 | 45.0 | 45.1 | 45.1 | 45.1 | 45.0 | 45.1 | 45.0 | 45.2 | 45.0 | 770.0 |
| TOTAL FAA COSTS | 84.1 | 45.1 | 45.0 | 45.1 | 45.1 | 45.1 | 45.0 | 45.1 | 45.0 | 45.2 | 45.0 | 1,580.1 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | | | |
| AVIONICS EQUIP | 62.2 | 69.7 | 80.4 | 84.7 | 92.5 | 101.7 | 124.5 | 147.4 | 173.5 | 194.6 | 204.7 | 2,465.0 |
| O & M | 110.3 | 118.0 | 125.1 | 131.8 | 138.1 | 136.1 | 143.9 | 152.2 | 162.2 | 170.4 | 180.3 | 1,864.9 |
| TOTAL USER COSTS | 172.5 | 187.7 | 205.5 | 216.5 | 230.6 | 237.8 | 268.4 | 299.6 | 335.7 | 365.0 | 385.0 | 4,329.9 |
| TOTAL COSTS | 256.6 | 232.8 | 250.5 | 261.6 | 275.7 | 282.9 | 313.4 | 344.7 | 380.7 | 410.2 | 430.0 | 5,910.0 |

TABLE A.6

DISCOUNTED ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 1

| | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | | | | | | | | |
| PASSENGER DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 29.8 | 54.2 | 73.8 | 89.5 | 101.7 | 114.4 | 123.8 | 130.6 | 135.2 | 137.8 | 148.4 | 155.9 |
| AIRCRAFT DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 43.4 | 78.9 | 107.6 | 130.4 | 148.2 | 164.9 | 177.3 | 186.1 | 191.9 | 195.0 | 204.2 | 210.2 |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 | 2.4 | 3.3 | 4.0 | 4.5 | 4.3 | 4.1 | 3.9 | 3.6 | 3.4 | 3.2 | 3.0 |
| TOTAL TERMINAL BENEFITS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 74.5 | 135.5 | 184.7 | 223.9 | 254.5 | 283.6 | 305.2 | 320.6 | 330.7 | 336.3 | 355.8 | 369.0 |
| ENROUTE CENTERS | | | | | | | | | | | | | | | | | |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 36.0 | 72.6 | 99.6 | 98.9 | 99.7 | 95.5 | 89.5 | 79.8 | 60.7 | 51.1 | 46.5 | 42.2 |
| ACCIDENT REDUCTION SAVINGS | .9 | .8 | .8 | .8 | .8 | .7 | .7 | .7 | .7 | .6 | .6 | .5 | .5 | .5 | .4 | .4 | .4 |
| TOTAL BENEFITS | .9 | .8 | .8 | .8 | .8 | 111.2 | 208.8 | 285.0 | 323.5 | 354.7 | 379.6 | 395.3 | 400.9 | 391.8 | 387.9 | 402.7 | 411.6 |
| FEDERAL AVIATION ADMIN COSTS | | | | | | | | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | | | | | | | | |
| WVAS | 2.4 | 3.6 | 2.9 | 1.8 | 1.6 | 1.5 | 1.4 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| T. AUTOMATION | 8.8 | 2.0 | 7.8 | 5.8 | 4.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| E. AUTOMATION | 9.4 | 9.7 | 9.1 | 8.3 | 7.5 | 6.8 | 6.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 1.7 | 2.1 | 1.9 | .8 | .7 | .6 | .6 | .5 | .5 | .4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 22.3 | 17.5 | 21.7 | 16.6 | 14.4 | 8.9 | 8.1 | 1.7 | .5 | .4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FACILITIES & EQUIPMENT | | | | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 3.5 | 2.7 | 3.0 | 2.3 | 2.1 | 2.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| T.AUTOMATION | 29.3 | 2.0 | 8.3 | 7.5 | 6.8 | 6.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| E.AUTOMATION | .8 | 9.1 | 8.3 | 13.5 | 13.7 | 18.6 | 16.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 7.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL F&E COSTS | 37.7 | 11.1 | 20.0 | 23.7 | 23.5 | 27.1 | 19.1 | 2.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | .2 | .3 | .4 | .5 | .6 | .6 | .6 | .5 | .5 | .4 | .4 | .3 | .3 | .3 |
| T.AUTOMATION | 0.0 | .5 | .6 | .7 | .8 | .8 | .8 | .8 | .7 | .6 | .6 | .6 | .5 | .4 | .4 | .4 | .3 |
| E.AUTOMATION | 0.0 | .1 | 1.8 | 2.4 | 4.2 | 5.7 | 7.7 | 8.9 | 7.0 | 5.6 | 4.5 | 3.8 | 3.5 | 3.2 | 2.9 | 2.6 | 2.4 |
| CENTRAL FLOW C. | 0.0 | 1.4 | 1.5 | 1.7 | 1.5 | 1.2 | 1.1 | 1.0 | 1.0 | .9 | .8 | .7 | .6 | .5 | .5 | .4 | .4 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL O&M COSTS | 0.0 | 2.0 | 3.9 | 4.9 | 6.8 | 8.1 | 10.2 | 11.2 | 9.3 | 7.7 | 6.4 | 5.6 | 5.0 | 4.5 | 4.1 | 3.7 | 3.4 |
| TOTAL FAA COSTS | 60.0 | 30.5 | 45.5 | 45.2 | 44.7 | 44.1 | 37.4 | 15.1 | 9.8 | 8.1 | 6.4 | 5.6 | 5.0 | 4.5 | 4.1 | 3.7 | 3.4 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | | | | | | | | |
| AVIONICS EQUIP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O & M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL USER COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL COSTS | 60.0 | 30.5 | 45.5 | 45.2 | 44.7 | 44.1 | 37.4 | 15.1 | 9.8 | 8.1 | 6.4 | 5.6 | 5.0 | 4.5 | 4.1 | 3.7 | 3.4 |

TABLE A.6 (cont.)

DISCOUNTED ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 1

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | |
| PASSENGER DELAY | 160.8 | 163.5 | 164.4 | 171.6 | 176.1 | 178.4 | 178.8 | 177.7 | 2,666.5 |
| AIRCRAFT DELAY | 213.4 | 214.2 | 213.1 | 214.6 | 214.1 | 211.9 | 208.5 | 203.7 | 3,531.8 |
| FAA STAFF SAVINGS | 2.8 | 2.6 | 2.4 | 2.2 | 2.0 | 1.9 | 1.7 | 1.6 | 57.9 |
| TOTAL TERMINAL BENEFITS | 376.9 | 380.3 | 379.9 | 388.4 | 392.3 | 392.2 | 389.0 | 382.9 | 6,256.3 |
| ENROUTE CENTERS | | | | | | | | | |
| FAA STAFF SAVINGS | 38.4 | 34.9 | 31.7 | 28.9 | 26.2 | 23.8 | 21.7 | 19.7 | 1,097.3 |
| ACCIDENT REDUCTION SAVINGS | .4 | .4 | .3 | .3 | .3 | .3 | .3 | .2 | 13.3 |
| TOTAL BENEFITS | 415.7 | 415.5 | 412.0 | 417.6 | 418.8 | 416.3 | 410.9 | 402.9 | 7,366.9 |
| FEDERAL AVIATION ADMIN COSTS | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.4 |
| T. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 28.9 |
| E. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 57.0 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.7 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 112.1 |
| FACILITIES & EQUIPMENT | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 15.7 |
| T.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 60.1 |
| E.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 80.9 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.6 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL F&E COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 164.3 |
| OPERATIONS & MAINTENANCE | | | | | | | | | |
| WVAS | .3 | .2 | .2 | .2 | .2 | .2 | .2 | .1 | 7.5 |
| T.AUTOMATION | .3 | .3 | .2 | .2 | .2 | .2 | .2 | .2 | 11.3 |
| E.AUTOMATION | 2.2 | 2.0 | 1.8 | 1.6 | 1.5 | 1.3 | 1.2 | 1.1 | 78.8 |
| CENTRAL FLOW C. | .4 | .3 | .3 | .3 | .2 | .2 | .2 | .2 | 17.3 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL O&M COSTS | 3.1 | 2.8 | 2.6 | 2.3 | 2.1 | 1.9 | 1.8 | 1.6 | 115.0 |
| TOTAL FAA COSTS | 3.1 | 2.8 | 2.6 | 2.3 | 2.1 | 1.9 | 1.8 | 1.6 | 391.4 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | |
| AVIONICS EQUIP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O & M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL USER COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL COSTS | 3.1 | 2.8 | 2.6 | 2.3 | 2.1 | 1.9 | 1.8 | 1.6 | 391.4 |

TABLE A.7

DISCOUNTED ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 2

| | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | | | | | | | |
| PASSENGER DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 56.9 | 103.6 | 141.2 | 171.2 | 194.5 | 246.1 | 286.7 | 317.9 | 341.1 | 357.4 | 383.2 |
| AIRCRAFT DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 82.5 | 150.0 | 204.6 | 248.0 | 281.8 | 352.0 | 407.1 | 449.3 | 480.4 | 502.2 | 530.5 |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 | 2.4 | 3.3 | 4.0 | 4.5 | 5.8 | 6.8 | 7.6 | 8.2 | 8.6 | 7.9 |
| TOTAL TERMINAL BENEFITS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 140.8 | 256.0 | 349.1 | 423.2 | 480.8 | 603.9 | 700.6 | 774.8 | 829.7 | 868.2 | 921.7 |
| ENROUTE CENTERS | | | | | | | | | | | | | | | | |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 38.1 | 76.4 | 104.8 | 101.3 | 99.7 | 95.5 | 89.5 | 79.8 | 67.5 | 61.4 | 55.2 |
| ACCIDENT REDUCTION SAVINGS | .9 | .8 | .8 | .8 | .8 | .7 | .7 | .7 | .7 | .6 | .6 | .5 | .5 | .5 | .4 | .4 |
| TOTAL BENEFITS | .9 | .8 | .8 | .8 | .8 | 179.6 | 333.2 | 454.6 | 525.1 | 581.1 | 700.0 | 790.6 | 855.0 | 897.7 | 930.0 | 977.3 |
| FEDERAL AVIATION ADMIN COSTS | | | | | | | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | | | | | | | |
| WVAS | 2.4 | 3.6 | 2.9 | 1.8 | 1.6 | 1.5 | 1.4 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| T. AUTOMATION | 8.8 | 2.0 | 7.8 | 5.8 | 4.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| E. AUTOMATION | 9.4 | 9.7 | 9.1 | 8.3 | 7.5 | 6.8 | 6.2 | 5.6 | 5.1 | 4.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 1.7 | 2.1 | 1.9 | .8 | .7 | .6 | .6 | .5 | .5 | .4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 10.0 | 7.3 | 4.1 | 1.4 | 1.0 | .9 | .8 | .8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 32.3 | 24.7 | 25.8 | 18.0 | 15.4 | 9.9 | 9.0 | 8.2 | 5.6 | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FACILITIES & EQUIPMENT | | | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 3.5 | 2.7 | 3.0 | 2.3 | 2.1 | 2.1 | 0.0 | 0.0 | .1 | .1 | .1 | .1 | .1 | 0.0 |
| T.AUTOMATION | 29.3 | 2.0 | 8.3 | 7.5 | 6.8 | 6.1 | 2.8 | 2.5 | 2.3 | 2.0 | 4.9 | 4.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| E.AUTOMATION | .8 | 9.1 | 8.3 | 13.5 | 13.7 | 18.6 | 16.9 | 15.4 | 14.0 | 12.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 7.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.9 | 6.1 | 7.2 | 8.2 | 3.9 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL F&E COSTS | 37.7 | 11.1 | 20.0 | 23.7 | 23.5 | 27.1 | 21.8 | 20.0 | 21.1 | 20.9 | 12.3 | 12.8 | 4.0 | .1 | .1 | 0.0 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | .2 | .3 | .4 | .5 | .6 | .6 | .6 | .5 | .5 | .4 | .4 | .3 | .3 |
| T.AUTOMATION | 0.0 | .5 | .6 | .7 | .8 | .8 | .8 | .8 | .8 | .8 | .8 | .8 | .8 | .7 | .7 | .6 |
| E.AUTOMATION | 0.0 | .1 | 1.7 | 2.4 | 4.2 | 5.7 | 7.7 | 8.9 | 9.5 | 9.8 | 9.9 | 8.2 | 6.9 | 5.9 | 5.2 | 4.8 |
| CENTRAL FLOW C. | 0.0 | 1.4 | 1.5 | 1.7 | 1.5 | 1.2 | 1.1 | 1.0 | 1.0 | .9 | .8 | .7 | .6 | .5 | .5 | .4 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .2 | .5 | .8 | 1.1 | 1.3 | 1.2 | 1.1 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL O&M COSTS | 0.0 | 2.0 | 3.8 | 4.9 | 6.8 | 8.1 | 10.2 | 11.3 | 11.8 | 12.3 | 12.5 | 10.9 | 9.8 | 8.9 | 7.9 | 7.2 |
| TOTAL FAA COSTS | 70.0 | 37.8 | 49.6 | 46.6 | 45.8 | 45.0 | 41.0 | 39.5 | 38.6 | 38.3 | 24.8 | 23.7 | 13.8 | 9.0 | 8.0 | 7.2 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | | | | | | | |
| AVIONICS EQUIP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 70.1 | 65.7 | 59.8 | 54.4 | 48.9 | 3.6 | 3.7 |
| O & M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8.9 | 9.8 | 10.8 | 11.2 | 11.5 | 13.3 |
| TOTAL USER COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 70.1 | 74.6 | 69.6 | 65.2 | 60.1 | 15.1 | 17.0 |
| TOTAL COSTS | 70.0 | 37.8 | 49.6 | 46.6 | 45.8 | 45.0 | 41.0 | 39.5 | 38.6 | 108.4 | 99.4 | 93.2 | 79.0 | 69.1 | 23.1 | 24.2 |

TABLE A.7 (cont.)

DISCOUNTED ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 2

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | |
| PASSENGER DELAY | 401.3 | 413.0 | 419.3 | 421.0 | 435.0 | 443.0 | 446.0 | 444.8 | 440.1 | 6,463.4 |
| AIRCRAFT DELAY | 549.6 | 560.8 | 565.4 | 564.6 | 570.7 | 571.0 | 566.5 | 558.1 | 546.6 | 8,741.6 |
| FAA STAFF SAVINGS | 7.4 | 6.8 | 6.3 | 5.8 | 5.3 | 4.9 | 4.5 | 4.1 | 3.8 | 109.3 |
| TOTAL TERMINAL BENEFITS | 958.3 | 980.6 | 991.0 | 991.4 | 1,011.0 | 1,018.9 | 1,017.0 | 1,007.0 | 990.5 | 15,314.3 |
| ENROUTE CENTERS | | | | | | | | | | |
| FAA STAFF SAVINGS | 49.7 | 44.5 | 39.8 | 35.6 | 31.6 | 28.1 | 25.0 | 22.3 | 20.0 | 1,165.8 |
| ACCIDENT REDUCTION SAVINGS | .4 | .4 | .4 | .3 | .3 | .3 | .3 | .3 | .2 | 13.3 |
| TOTAL BENEFITS | 1,008.3 | 1,025.4 | 1,031.2 | 1,027.3 | 1,043.0 | 1,047.3 | 1,042.3 | 1,029.6 | 1,010.7 | 16,493.4 |
| FEDERAL AVIATION ADMIN COSTS | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.4 |
| T. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 28.9 |
| E. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 72.5 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.7 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 26.3 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 153.9 |
| FACILITIES & EQUIPMENT | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.1 |
| T.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 79.0 |
| E.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 123.0 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.6 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 30.4 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL F&E COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 256.2 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | |
| WVAS | .3 | .3 | .2 | .2 | .2 | .2 | .2 | .2 | .1 | 7.5 |
| T.AUTOMATION | .5 | .5 | .4 | .4 | .4 | .3 | .3 | .3 | .3 | 14.4 |
| E.AUTOMATION | 4.3 | 3.9 | 3.6 | 3.3 | 3.0 | 2.7 | 2.4 | 2.2 | 2.0 | 118.3 |
| CENTRAL FLOW C. | .4 | .4 | .3 | .3 | .3 | .2 | .2 | .2 | .2 | 17.3 |
| DABS | 1.0 | .9 | .8 | .8 | .7 | .6 | .6 | .5 | .4 | 12.3 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL O&M COSTS | 6.5 | 6.0 | 5.4 | 4.9 | 4.5 | 4.1 | 3.7 | 3.4 | 3.0 | 169.8 |
| TOTAL FAA COSTS | 6.5 | 6.0 | 5.4 | 4.9 | 4.5 | 4.1 | 3.7 | 3.4 | 3.0 | 579.9 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | |
| AVIONICS EQUIP | 4.8 | 4.0 | 3.7 | 13.3 | 13.3 | 13.3 | 11.9 | 12.9 | 13.3 | 396.7 |
| O & M | 14.6 | 15.5 | 16.0 | 14.6 | 15.0 | 14.2 | 13.5 | 12.7 | 12.1 | 193.6 |
| TOTAL USER COSTS | 19.4 | 19.5 | 19.6 | 27.9 | 28.3 | 27.5 | 25.3 | 25.7 | 25.4 | 590.3 |
| TOTAL COSTS | 25.9 | 25.4 | 25.1 | 32.9 | 32.7 | 31.6 | 29.0 | 29.0 | 28.5 | 1,170.2 |

TABLE A.8

DISCOUNTED ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 3

| | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | | | | | | | |
| PASSENGER DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 56.9 | 103.6 | 141.2 | 171.2 | 194.5 | 246.1 | 286.7 | 317.9 | 341.1 | 357.4 | 383.2 |
| AIRCRAFT DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 82.5 | 150.0 | 204.6 | 248.0 | 281.8 | 352.0 | 407.1 | 449.3 | 480.4 | 502.2 | 530.5 |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 | 2.4 | 3.3 | 4.0 | 4.5 | 5.8 | 6.8 | 7.6 | 8.2 | 8.6 | 7.9 |
| TOTAL TERMINAL BENEFITS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 140.8 | 256.0 | 349.1 | 423.2 | 480.8 | 603.9 | 700.6 | 774.8 | 829.7 | 868.2 | 921.7 |
| ENROUTE CENTERS | | | | | | | | | | | | | | | | |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 38.1 | 76.4 | 104.8 | 101.3 | 99.7 | 95.5 | 89.5 | 79.8 | 81.4 | 82.1 | 72.8 |
| ACCIDENT REDUCTION SAVINGS | .9 | .8 | .8 | .8 | .8 | .7 | .7 | .7 | .7 | .6 | .6 | .5 | .5 | .5 | .4 | .4 |
| TOTAL BENEFITS | .9 | .8 | .8 | .8 | .8 | 179.6 | 333.2 | 454.6 | 525.1 | 581.1 | 700.0 | 790.6 | 855.0 | 911.5 | 950.7 | 994.8 |
| FEDERAL AVIATION ADMIN COSTS | | | | | | | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | | | | | | | |
| WVAS | 2.4 | 3.6 | 2.9 | 1.8 | 1.6 | 1.5 | 1.4 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| T. AUTOMATION | 8.8 | 2.0 | 7.8 | 5.8 | 4.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| E. AUTOMATION | 9.4 | 9.7 | 9.1 | 8.3 | 7.5 | 6.8 | 6.2 | 5.6 | 5.1 | 4.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 1.7 | 2.1 | 1.9 | .8 | .7 | .6 | .6 | .5 | .5 | .4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 10.0 | 7.3 | 4.1 | 1.4 | 1.0 | .9 | .8 | .8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 32.3 | 24.7 | 25.8 | 18.0 | 15.4 | 9.9 | 9.0 | 8.2 | 5.6 | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FACILITIES & EQUIPMENT | | | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 3.5 | 2.7 | 3.0 | 2.3 | 2.1 | 2.1 | 0.0 | 0.0 | .1 | .1 | .1 | .1 | .1 | 0.0 |
| T.AUTOMATION | 29.3 | 2.0 | 8.3 | 7.5 | 6.8 | 6.1 | 2.8 | 2.5 | 2.3 | 2.1 | 4.9 | 4.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| E.AUTOMATION | .8 | 9.1 | 8.3 | 13.5 | 13.7 | 18.6 | 16.9 | 15.4 | 14.0 | 12.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 7.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.2 | 12.0 | 13.6 | 9.6 | 8.8 | 8.5 | 9.7 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL F&E COSTS | 37.7 | 11.1 | 20.0 | 23.7 | 23.5 | 27.1 | 21.8 | 20.0 | 23.5 | 26.8 | 18.6 | 14.2 | 8.8 | 8.6 | 9.8 | 0.0 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | .2 | .3 | .4 | .5 | .6 | .6 | .6 | .5 | .5 | .4 | .4 | .3 | .3 |
| T.AUTOMATION | 0.0 | .5 | .6 | .7 | .8 | .8 | .8 | .8 | .8 | .8 | .8 | .8 | .8 | .7 | .7 | .6 |
| E.AUTOMATION | 0.0 | .1 | 1.7 | 2.4 | 4.2 | 5.7 | 7.7 | 8.9 | 9.5 | 9.8 | 9.9 | 8.2 | 6.9 | 5.9 | 5.2 | 4.8 |
| CENTRAL FLOW C. | 0.0 | 1.4 | 1.5 | 1.7 | 1.5 | 1.2 | 1.1 | 1.0 | 1.0 | .9 | .8 | .7 | .6 | .5 | .5 | .4 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .3 | .8 | 1.6 | 2.2 | 2.6 | 3.0 | 3.2 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL O&M COSTS | 0.0 | 2.0 | 3.8 | 4.9 | 6.8 | 8.1 | 10.2 | 11.3 | 11.8 | 12.4 | 12.9 | 11.7 | 10.9 | 10.2 | 9.7 | 9.4 |
| TOTAL FAA COSTS | 70.0 | 37.8 | 49.6 | 46.6 | 45.8 | 45.0 | 41.0 | 39.5 | 41.0 | 44.2 | 31.5 | 25.9 | 19.7 | 18.8 | 19.5 | 9.4 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | | | | | | | |
| AVIONICS EQUIP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 70.1 | 65.7 | 59.8 | 54.4 | 48.9 | 3.6 | 3.7 |
| O & M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8.9 | 9.8 | 10.8 | 11.2 | 11.5 | 13.3 |
| TOTAL USER COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 70.1 | 74.6 | 69.6 | 65.2 | 60.1 | 15.1 | 17.0 |
| TOTAL COSTS | 70.0 | 37.8 | 49.6 | 46.6 | 45.8 | 45.0 | 41.0 | 39.5 | 41.0 | 114.3 | 106.1 | 95.4 | 84.9 | 78.9 | 34.6 | 26.4 |

TABLE A.8 (cont.)

DISCOUNTED ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 3

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | |
| PASSENGER DELAY | 401.3 | 413.0 | 419.3 | 421.0 | 435.0 | 443.0 | 446.0 | 444.8 | 440.1 | 6,463.4 |
| AIRCRAFT DELAY | 549.6 | 560.8 | 565.4 | 564.6 | 570.7 | 571.0 | 566.5 | 558.1 | 546.6 | 8,741.6 |
| FAA STAFF SAVINGS | 7.4 | 6.8 | 6.3 | 5.8 | 5.3 | 4.9 | 4.5 | 4.1 | 3.8 | 109.3 |
| TOTAL TERMINAL BENEFITS | 958.3 | 980.6 | 991.0 | 991.4 | 1,011.0 | 1,018.9 | 1,017.0 | 1,007.0 | 990.5 | 15,314.3 |
| ENROUTE CENTERS | | | | | | | | | | |
| FAA STAFF SAVINGS | 64.5 | 56.6 | 49.6 | 43.4 | 37.2 | 31.7 | 27.3 | 23.7 | 20.5 | 1,275.7 |
| ACCIDENT REDUCTION SAVINGS | .4 | .4 | .4 | .3 | .3 | .3 | .3 | .3 | .2 | 13.3 |
| TOTAL BENEFITS | 1,023.2 | 1,037.6 | 1,041.0 | 1,035.1 | 1,048.5 | 1,051.0 | 1,044.6 | 1,031.0 | 1,011.2 | 16,603.3 |
| FEDERAL AVIATION ADMIN COSTS | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.4 |
| T. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 28.9 |
| E. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 72.5 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.7 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 26.3 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 153.9 |
| FACILITIES & EQUIPMENT | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.1 |
| T.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 79.1 |
| E.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 123.0 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.6 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 69.5 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL F&F COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 295.3 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | |
| WVAS | .3 | .3 | .2 | .2 | .2 | .2 | .2 | .2 | .1 | 7.5 |
| T.AUTOMATION | .5 | .5 | .4 | .4 | .4 | .3 | .3 | .3 | .3 | 14.4 |
| E.AUTOMATION | 4.3 | 3.9 | 3.6 | 3.3 | 3.0 | 2.7 | 2.4 | 2.2 | 2.0 | 118.3 |
| CENTRAL FLOW C. | .4 | .4 | .3 | .3 | .3 | .2 | .2 | .2 | .2 | 17.3 |
| DABS | 2.9 | 2.7 | 2.4 | 2.2 | 2.0 | 1.8 | 1.7 | 1.5 | 1.4 | 32.3 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL O&M COSTS | 8.5 | 7.7 | 7.0 | 6.4 | 5.8 | 5.3 | 4.8 | 4.4 | 4.0 | 189.8 |
| TOTAL FAA COSTS | 8.5 | 7.7 | 7.0 | 6.4 | 5.8 | 5.3 | 4.8 | 4.4 | 4.0 | 639.0 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | |
| AVIONICS EQUIP | 4.8 | 4.0 | 3.7 | 13.3 | 13.3 | 13.3 | 11.9 | 12.9 | 13.3 | 396.7 |
| O & M | 14.6 | 15.5 | 16.0 | 14.6 | 15.0 | 14.2 | 13.5 | 12.7 | 12.1 | 193.6 |
| TOTAL USER COSTS | 19.4 | 19.5 | 19.6 | 27.9 | 28.3 | 27.5 | 25.3 | 25.7 | 25.4 | 590.3 |
| TOTAL COSTS | 27.9 | 27.2 | 26.7 | 34.3 | 34.1 | 32.8 | 30.1 | 30.0 | 29.4 | 1,229.3 |

TABLE A.9

DISCOUNTED ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 4

| | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | | | | | | | |
| PASSENGER DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 56.9 | 103.6 | 141.2 | 171.2 | 194.5 | 246.1 | 286.7 | 317.9 | 341.1 | 357.4 | 383.2 |
| AIRCRAFT DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 82.5 | 150.0 | 204.6 | 248.0 | 281.8 | 352.0 | 407.1 | 449.3 | 480.4 | 502.2 | 530.5 |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 | 2.4 | 3.3 | 4.0 | 4.5 | 5.8 | 6.8 | 7.6 | 8.2 | 8.6 | 7.9 |
| TOTAL TERMINAL BENEFITS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 140.8 | 256.0 | 349.1 | 423.2 | 480.8 | 603.9 | 700.6 | 774.8 | 829.7 | 868.2 | 921.7 |
| ENROUTE CENTERS | | | | | | | | | | | | | | | | |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 38.1 | 76.4 | 104.8 | 101.3 | 99.7 | 95.5 | 89.5 | 79.8 | 67.5 | 61.4 | 55.2 |
| ACCIDENT REDUCTION | | | | | | | | | | | | | | | | |
| SAVINGS | .9 | .8 | .8 | .8 | .8 | .8 | .7 | .7 | .7 | .6 | 1.8 | 2.7 | 3.5 | 3.3 | 4.6 | 5.2 |
| TOTAL BENEFITS | .9 | .8 | .8 | .8 | .8 | 179.6 | 333.2 | 454.6 | 525.1 | 581.1 | 701.1 | 792.9 | 858.0 | 900.5 | 934.1 | 982.1 |
| FEDERAL AVIATION ADMIN COSTS | | | | | | | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | | | | | | | |
| WVAS | 2.4 | 3.6 | 2.9 | 1.8 | 1.6 | 1.5 | 1.4 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| T. AUTOMATION | 8.8 | 2.0 | 7.8 | 5.8 | 4.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| E. AUTOMATION | 9.4 | 9.7 | 9.1 | 8.3 | 7.5 | 6.8 | 6.2 | 5.6 | 5.1 | 4.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 1.7 | 2.1 | 1.9 | .8 | .7 | .6 | .6 | .5 | .5 | .4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 10.0 | 7.3 | 4.1 | 1.4 | 1.0 | .9 | .8 | .8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 2.7 | 2.5 | 1.1 | 1.0 | .9 | .8 | .5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 32.3 | 27.5 | 28.3 | 19.1 | 16.5 | 10.8 | 9.8 | 8.7 | 5.6 | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FACILITIES & EQUIPMENT | | | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 3.5 | 2.7 | 3.0 | 2.3 | 2.1 | 2.1 | 0.0 | 0.0 | .1 | .1 | .1 | .1 | .1 | 0.0 |
| T.AUTOMATION | 29.3 | 2.0 | 8.3 | 7.5 | 6.8 | 6.1 | 2.8 | 2.5 | 2.3 | 2.0 | 4.9 | 4.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| E.AUTOMATION | .8 | 9.1 | 8.3 | 13.5 | 13.7 | 18.6 | 16.9 | 15.4 | 14.0 | 12.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 7.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.9 | 6.1 | 7.2 | 8.2 | 3.9 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .5 | .6 | 1.0 | 1.1 | .6 | 0.0 | 0.0 | 0.0 |
| TOTAL F&E COSTS | 37.7 | 11.1 | 20.0 | 23.7 | 23.5 | 27.1 | 21.8 | 20.0 | 21.6 | 21.5 | 13.2 | 13.8 | 4.6 | .1 | .1 | 0.0 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | .2 | .3 | .4 | .5 | .6 | .6 | .6 | .5 | .5 | .4 | .4 | .3 | .3 |
| T.AUTOMATION | 0.0 | .5 | .6 | .7 | .8 | .8 | .8 | .8 | .8 | .8 | .8 | .8 | .8 | .7 | .7 | .6 |
| E.AUTOMATION | 0.0 | .1 | 1.7 | 2.4 | 4.2 | 5.7 | 7.7 | 8.9 | 9.5 | 9.8 | 9.9 | 8.2 | 6.9 | 5.9 | 5.2 | 4.8 |
| CENTRAL FLOW C. | 0.0 | 1.4 | 1.5 | 1.7 | 1.5 | 1.2 | 1.1 | 1.0 | 1.0 | .9 | .8 | .7 | .6 | .6 | .5 | .4 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .2 | .4 | .8 | 1.1 | 1.3 | 1.2 | 1.1 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .1 | .2 | .4 | .5 | .6 | .5 | .5 |
| TOTAL O&M COSTS | 0.0 | 2.0 | 3.8 | 4.9 | 6.8 | 8.1 | 10.2 | 11.3 | 11.8 | 12.4 | 12.6 | 11.3 | 10.4 | 9.5 | 8.4 | 7.7 |
| TOTAL FAA COSTS | 70.0 | 40.5 | 52.1 | 47.7 | 46.8 | 45.9 | 41.8 | 40.0 | 39.0 | 39.0 | 25.9 | 25.1 | 15.0 | 9.6 | 8.5 | 7.7 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | | | | | | | |
| AVIONICS EQUIP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 88.2 | 79.4 | 70.4 | 63.2 | 57.9 | 11.8 | 10.4 |
| O & M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.4 | 14.5 | 17.5 | 19.7 | 21.4 | 20.4 |
| TOTAL USER COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 88.2 | 89.8 | 84.9 | 80.7 | 77.6 | 33.2 | 30.9 |
| TOTAL COSTS | 70.0 | 40.5 | 52.1 | 47.7 | 46.8 | 45.9 | 41.8 | 40.0 | 39.0 | 127.2 | 115.7 | 109.9 | 95.7 | 87.2 | 41.7 | 38.5 |

TABLE A.9 (cont.)

DISCOUNTED ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 4

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | |
| PASSENGER DELAY | 401.3 | 413.0 | 419.3 | 421.0 | 435.0 | 443.0 | 446.0 | 444.8 | 440.1 | 6,463.4 |
| AIRCRAFT DELAY | 549.6 | 560.8 | 565.4 | 564.6 | 570.7 | 571.0 | 566.5 | 558.1 | 546.6 | 8,741.6 |
| FAA STAFF SAVINGS | 7.4 | 6.8 | 6.3 | 5.8 | 5.3 | 4.9 | 4.5 | 4.1 | 3.8 | 109.3 |
| TOTAL TERMINAL BENEFITS | 958.3 | 980.6 | 991.0 | 991.4 | 1,011.0 | 1,018.9 | 1,017.0 | 1,007.0 | 990.5 | 15,314.3 |
| ENROUTE CENTERS | | | | | | | | | | |
| FAA STAFF SAVINGS | 49.7 | 44.5 | 39.8 | 35.6 | 31.6 | 28.1 | 25.0 | 22.3 | 20.0 | 1,165.8 |
| ACCIDENT REDUCTION SAVINGS | 4.9 | 6.0 | 6.2 | 6.4 | 6.0 | 5.6 | 5.3 | 5.0 | 4.7 | 78.6 |
| TOTAL BENEFITS | 1,012.8 | 1,031.1 | 1,037.0 | 1,033.4 | 1,048.6 | 1,052.6 | 1,047.3 | 1,034.3 | 1,015.1 | 16,558.7 |
| FEDERAL AVIATION ADMIN COSTS | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.4 |
| T. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 28.9 |
| E. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 72.5 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.7 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 26.3 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.6 |
| TOTAL E&D COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 163.5 |
| FACILITIES & EQUIPMENT | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.1 |
| T.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 79.0 |
| F.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 123.0 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.6 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 30.4 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.8 |
| TOTAL F&E COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 259.9 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | |
| WVAS | .3 | .3 | .2 | .2 | .2 | .2 | .2 | .2 | .1 | 7.5 |
| T.AUTOMATION | .5 | .5 | .4 | .4 | .4 | .3 | .3 | .3 | .3 | 14.4 |
| F.AUTOMATION | 4.3 | 3.9 | 3.6 | 3.3 | 3.0 | 2.7 | 2.4 | 2.2 | 2.0 | 118.3 |
| CENTRAL FLOW C. | .4 | .4 | .3 | .3 | .3 | .2 | .2 | .2 | .2 | 17.3 |
| DABS | 1.0 | .9 | .8 | .7 | .7 | .6 | .6 | .5 | .5 | 12.3 |
| IPC | .4 | .4 | .4 | .3 | .3 | .3 | .2 | .2 | .2 | 5.5 |
| TOTAL O&M COSTS | 7.0 | 6.4 | 5.8 | 5.2 | 4.8 | 4.3 | 3.9 | 3.6 | 3.2 | 175.3 |
| TOTAL FAA COSTS | 7.0 | 6.4 | 5.8 | 5.2 | 4.8 | 4.3 | 3.9 | 3.6 | 3.2 | 598.8 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | |
| AVIONICS EQUIP | 9.1 | 7.8 | 6.6 | 11.2 | 14.4 | 15.4 | 16.1 | 16.3 | 16.9 | 495.2 |
| O & M | 19.4 | 18.3 | 17.1 | 14.4 | 14.0 | 13.7 | 13.2 | 12.8 | 12.4 | 239.2 |
| TOTAL USER COSTS | 28.5 | 26.1 | 23.8 | 25.6 | 28.4 | 29.1 | 29.3 | 29.1 | 29.3 | 734.4 |
| TOTAL COSTS | 35.5 | 32.4 | 29.5 | 30.9 | 33.1 | 33.4 | 33.3 | 32.7 | 32.6 | 1,333.2 |

TABLE A.10

DISCOUNTED ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 5

| | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | | | | | | | |
| PASSENGER DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 56.9 | 103.6 | 141.2 | 171.2 | 194.5 | 246.1 | 286.7 | 317.9 | 341.1 | 357.4 | 383.2 |
| AIRCRAFT DELAY | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 82.5 | 150.0 | 204.6 | 248.0 | 281.8 | 352.0 | 407.1 | 449.3 | 480.4 | 502.2 | 530.5 |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 | 2.4 | 3.3 | 4.0 | 4.5 | 5.8 | 6.8 | 7.6 | 8.2 | 8.6 | 7.9 |
| TOTAL TERMINAL BENEFITS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 140.8 | 256.0 | 349.1 | 423.2 | 480.8 | 603.9 | 700.6 | 774.8 | 829.7 | 868.2 | 921.7 |
| ENROUTE CENTERS | | | | | | | | | | | | | | | | |
| FAA STAFF SAVINGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 38.1 | 76.4 | 104.8 | 101.3 | 99.7 | 95.5 | 89.5 | 79.8 | 81.4 | 82.1 | 72.8 |
| ACCIDENT REDUCTION SAVINGS | .9 | .8 | .8 | .8 | .8 | .8 | .7 | .7 | .7 | .6 | 2.5 | 5.4 | 7.0 | 8.4 | 9.5 | 11.2 |
| TOTAL BENEFITS | .9 | .8 | .8 | .8 | .8 | 179.6 | 333.2 | 454.6 | 525.1 | 581.1 | 701.8 | 795.5 | 861.6 | 919.5 | 959.7 | 1,005.6 |
| FEDERAL AVIATION ADMIN COSTS | | | | | | | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | | | | | | | |
| WVAS | 2.4 | 3.6 | 2.9 | 1.8 | 1.6 | 1.5 | 1.4 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| T. AUTOMATION | 8.8 | 2.0 | 7.8 | 5.8 | 4.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| E. AUTOMATION | 9.4 | 9.7 | 9.1 | 8.3 | 7.5 | 6.8 | 6.2 | 5.6 | 5.1 | 4.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 1.7 | 2.1 | 1.9 | .8 | .7 | .6 | .6 | .5 | .5 | .4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 10.0 | 7.3 | 4.1 | 1.4 | 1.0 | .9 | .8 | .8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| IPC | 0.0 | 2.7 | 2.5 | 1.1 | 1.0 | .9 | .8 | .5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL E&D COSTS | 32.3 | 27.5 | 28.3 | 19.1 | 16.5 | 10.8 | 9.8 | 8.7 | 5.6 | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FACILITIES & EQUIPMENT | | | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 3.5 | 2.7 | 3.0 | 2.3 | 2.1 | 2.1 | 0.0 | 0.0 | .1 | .1 | .1 | .1 | .1 | 0.0 |
| T.AUTOMATION | 29.3 | 2.0 | 8.3 | 7.5 | 6.8 | 6.1 | 2.8 | 2.5 | 2.3 | 2.0 | 4.9 | 4.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| E.AUTOMATION | .8 | 9.1 | 8.3 | 13.5 | 13.7 | 18.6 | 16.9 | 15.4 | 14.0 | 12.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CENTRAL FLOW C. | 7.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.2 | 12.0 | 13.6 | 9.6 | 8.8 | 8.5 | 9.7 | 0.0 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .7 | 1.5 | 1.9 | 1.8 | 1.6 | 1.4 | 1.3 | 0.0 |
| TOTAL F&E COSTS | 37.7 | 11.1 | 20.0 | 23.7 | 23.5 | 27.1 | 21.8 | 20.0 | 24.2 | 28.2 | 20.5 | 15.9 | 10.4 | 10.1 | 11.1 | 0.0 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | .2 | .3 | .4 | .5 | .6 | .6 | .6 | .5 | .5 | .4 | .4 | .3 | .3 |
| T.AUTOMATION | 0.0 | .5 | .6 | .7 | .8 | .8 | .8 | .8 | .8 | .8 | .8 | .8 | .8 | .7 | .7 | .6 |
| E.AUTOMATION | 0.0 | .1 | 1.7 | 2.4 | 4.2 | 5.7 | 7.7 | 8.9 | 9.5 | 9.8 | 9.9 | 8.2 | 6.9 | 5.9 | 5.2 | 4.8 |
| CENTRAL FLOW C. | 0.0 | 1.4 | 1.5 | 1.7 | 1.5 | 1.2 | 1.1 | 1.0 | 1.0 | .9 | .8 | .7 | .6 | .6 | .5 | .4 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .3 | .9 | 1.6 | 2.2 | 2.6 | 3.0 | 3.2 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | .1 | .4 | .7 | 1.0 | 1.2 | 1.3 | 1.4 |
| TOTAL O&M COSTS | 0.0 | 2.0 | 3.8 | 4.9 | 6.8 | 8.1 | 10.2 | 11.3 | 11.8 | 12.5 | 13.3 | 12.4 | 11.8 | 11.4 | 11.0 | 10.8 |
| TOTAL FAA COSTS | 70.0 | 40.5 | 52.1 | 47.7 | 46.8 | 45.9 | 41.8 | 40.0 | 41.7 | 45.8 | 33.9 | 28.3 | 22.2 | 21.4 | 22.1 | 10.8 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | | | | | | | |
| AVIONICS EQUIP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 91.4 | 86.4 | 78.4 | 73.0 | 68.5 | 16.4 | 16.7 |
| O & M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 17.5 | 22.8 | 26.7 | 29.6 | 29.0 | 28.2 |
| TOTAL USER COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 91.4 | 103.9 | 101.2 | 99.7 | 98.2 | 45.4 | 44.9 |
| TOTAL COSTS | 70.0 | 40.5 | 52.1 | 47.7 | 46.8 | 45.9 | 41.8 | 40.0 | 41.7 | 137.2 | 137.8 | 129.5 | 121.9 | 119.6 | 67.6 | 55.7 |

TABLE A.10 (cont.)

DISCOUNTED ANNUAL BENEFITS AND COSTS
OF THE UG3RD ATC SYSTEM
MILLIONS 1975 DOLLARS
CONFIGURATION 5

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| BENEFITS | | | | | | | | | | |
| TERMINAL AREAS | | | | | | | | | | |
| PASSENGER DELAY | 401.3 | 413.0 | 419.3 | 421.0 | 435.0 | 443.0 | 446.0 | 444.8 | 440.1 | 6,463.4 |
| AIRCRAFT DELAY | 549.6 | 560.8 | 565.4 | 564.6 | 570.7 | 571.0 | 566.5 | 558.1 | 546.6 | 8,741.6 |
| FAA STAFF SAVINGS | 7.4 | 6.8 | 6.3 | 5.8 | 5.3 | 4.9 | 4.5 | 4.1 | 3.8 | 109.3 |
| TOTAL TERMINAL BENEFITS | 958.3 | 980.6 | 991.0 | 991.4 | 1,011.0 | 1,018.9 | 1,017.0 | 1,007.0 | 990.5 | 15,314.3 |
| ENROUTE CENTERS | | | | | | | | | | |
| FAA STAFF SAVINGS | 64.5 | 56.6 | 49.6 | 43.4 | 37.2 | 31.7 | 27.3 | 23.7 | 20.5 | 1,275.7 |
| ACCIDENT REDUCTION SAVINGS | 12.5 | 13.4 | 14.1 | 14.6 | 13.7 | 12.9 | 12.1 | 11.4 | 10.7 | 166.9 |
| TOTAL BENEFITS | 1,035.2 | 1,050.6 | 1,054.7 | 1,049.4 | 1,062.0 | 1,063.5 | 1,056.4 | 1,042.1 | 1,021.6 | 16,756.9 |
| FEDERAL AVIATION ADMIN COSTS | | | | | | | | | | |
| ENGINEERING & DEVELOPMENT | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.4 |
| T. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 28.9 |
| E. AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 72.5 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.7 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 26.3 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.6 |
| TOTAL E&D COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 163.5 |
| FACILITIES & EQUIPMENT | | | | | | | | | | |
| WVAS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.1 |
| T.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 79.0 |
| E.AUTOMATION | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 123.0 |
| CENTRAL FLOW C. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.6 |
| DABS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 69.5 |
| IPC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.2 |
| TOTAL F&E COSTS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 305.4 |
| OPERATIONS & MAINTENANCE | | | | | | | | | | |
| WVAS | .3 | .3 | .2 | .2 | .2 | .2 | .2 | .2 | .1 | 7.5 |
| T.AUTOMATION | .5 | .5 | .4 | .4 | .4 | .3 | .3 | .3 | .3 | 14.4 |
| E.AUTOMATION | 4.3 | 3.9 | 3.6 | 3.3 | 3.0 | 2.7 | 2.4 | 2.2 | 2.0 | 118.3 |
| CENTRAL FLOW C. | .4 | .4 | .3 | .3 | .3 | .2 | .2 | .2 | .2 | 17.3 |
| DABS | 2.9 | 2.7 | 2.4 | 2.2 | 2.0 | 1.8 | 1.7 | 1.5 | 1.4 | 32.4 |
| IPC | 1.3 | 1.2 | 1.1 | 1.0 | .9 | .8 | .7 | .7 | .6 | 14.4 |
| TOTAL O&M COSTS | 9.8 | 8.9 | 8.1 | 7.4 | 6.7 | 6.1 | 5.5 | 5.0 | 4.6 | 204.2 |
| TOTAL FAA COSTS | 9.8 | 8.9 | 8.1 | 7.4 | 6.7 | 6.1 | 5.5 | 5.0 | 4.6 | 673.2 |
| AIRWAY SYSTEMS USER COSTS | | | | | | | | | | |
| AVIONICS EQUIP | 17.5 | 16.8 | 16.6 | 16.6 | 18.5 | 19.9 | 21.3 | 21.7 | 20.8 | 600.6 |
| O & M | 27.2 | 26.1 | 24.8 | 22.3 | 21.4 | 20.6 | 19.9 | 19.0 | 18.3 | 353.5 |
| TOTAL USER COSTS | 44.7 | 42.8 | 41.5 | 38.9 | 39.9 | 40.5 | 41.2 | 40.8 | 39.1 | 954.1 |
| TOTAL COSTS | 54.5 | 51.8 | 49.6 | 46.3 | 46.6 | 46.6 | 46.8 | 45.8 | 43.7 | 1,627.4 |

## APPENDIX B

AIRPORT NETWORK MODEL

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# APPENDIX B

## Airport Network Model

### B.1 Airline Fleet Routing Model: FA-4

#### B.1.1 FA-4 Introduction - The Fleet Routing Problem Discussed

For this analysis an airline fleet routing model was used to predict the level of aircraft activity among the 23 largest metropolitan areas. An airline reacts to growth in passenger demand in two ways: first, by adjusting aircraft size and frequency of service to accommodate the increased demand, and second, by altering routings so that what was once a multistop flight can bypass intermediate stops and fly direct. This leaves the intermediate passengers to be picked up by another airplane.

For an airline, the adjustment of frequency and aircraft size in a city pair market is a balance between the economy of larger vehicles and the demand stimulation effect of higher frequencies. The adjustment among several markets interconnected by various aircraft flights is complex. In general as passenger demand grows, flight frequencies are added, up to a point. Growth in aircraft size characterizes the behavior in markets with adequate frequency of departures already developed. In addition, it is also known that nonstop service replaces multistop service as demand grows. Finally, growth in demand is generally met by at least some improvement in service. This improvement stimulates additional growth in demand.

#### B.1.2 FA-4 Model Description

FA-4 is intended to simulate the behavior of a profit-seeking airline faced with a set of city pair markets. The demand for service for these markets depends on the level of service, among other things. At low frequencies, additional frequencies increase demand, while above some higher number of flights a day, additional

services represent little improvement and create negligible increases in demand. The airline has several aircraft types, of various sizes. These aircraft can be routed to combine several markets on a single flight, or they can be flown nonstop serving only one city pair. FA-4 simulates the airline's decisions in this respect.

FA-4 is a linear program. Thus the rules of the market place and of practicality are expressed as a series of constraints the airlines must obey. The solution procedure may be thought of as trying out every imaginable combination of aircraft, routes, and frequencies. The costs and incomes in each case are added up, and the case with the greatest excess of income over cost is the best.

The rules the solution must obey are the following:

1. The total cost of a system of airplanes flight is the sum of the direct operating costs for each aircraft-route employed and the indirect operating costs proportional to passengers and passenger miles. Landing fees are included, but administrative overheads do not affect the routing decisions. They are taken out of the profits, if any.

2. The total income of the system is the sum of all the passengers carried times their fares.

3. No passenger is carried unless there are sufficient seats for him on each link of his flight. A maximum load factor (53 percent for this analysis) establishes the effective average aircraft capacities.

4. No more passengers are carried than the demand indicates, and the demand is limited by the level of service. The upper bound on the passengers is the upper bound on the income in each market.

5. Finally there may be a maximum number of departures allowed at any specific airport, due to capacity constraints or for some other reason.

### B.1.3 FA-4 - The Numbers used for Cost and Demand

The 23 city network evaluated by FA-4 was first run for the year 1975. Demand, fare, and cost data for the year 1974

were used for calibration. The only changes for runs simulating 1985, 1990, 1995, and 2000 were the demands. The 1974 dollars were used for both costs and fares throughout.

Airlines costs were expressed as long-term average costs, including both depreciation and return on capital. This means vehicles could be bought or sold as the need arose. In fact, a significant increase in the wide-body fleet was predicted by the model.

Table B.1 lists the aircraft costs for the two vehicles postulated in this analysis. While it was possible to introduce intermediate vehicle sizes, FA-4 could artificially create middle-size aircraft by mixing service with the two extremes. One service with the wide aircraft and two with the small was the equivalent of three services with a 153-seat aircraft. This approximation reduced the size of the problem without sacrificing accuracy.

Indirect operating costs were estimated to be \$0.025 per revenue passenger mile and \$8.00 per passenger boarding. These figures represented long-run marginal costs, which include a certain amount of lower management and sales overheads as well as the direct handling costs. Fares were approximated by the formula \$16.80 + \$0.0692/mile. This was 5 percent over 1974 fares.

Historical passenger travel for 1974 and the corresponding frequencies of service were used to calibrate the demand-frequency function for each city pair.
The function used was -

$$\text{PAX} = \text{K} \,/\, (\text{FLIGHT TIME} + 2.1 + 6/\text{FREQ})^{1.3}$$

2.1 represents time for access, egress, and boarding
6/FREQ represents average wait time
1.3 is the time elasticity of demand
K is the calibration constant

TABLE B-1

Aircraft Costs 1/

| NAME | SMALL | WIDE |
|---|---|---|
| Seats | 80 | 300 |
| Load Factor Maximum | 53% | 53% |
| Cost Per Hour | $775 | $2,214 |
| Speed | 510 mph | 510 mph |
| Take-off and Climb Time | 15 min. | 15 min. |
| Landing Fee and IOC | $156 | $328 |

1/ These costs are above 1974 reported costs because depreciation has been replaced by a dry lease cost, which includes a return on investment. The 80-seat vehicle is particularly above B-737 and DC-9 costs because these two aircraft are short range, while the 23-city network operated long-range flights.

In the sum for total frequency, frequencies of multistop flights were given a value less than one. The frequency used here is the total air carrier frequency divided by the level of competition. The level of competition is the inverse of the largest market share. Thus for two carriers each carrying 50 percent of the market with matching frequencies, each must count their flight as only 1/2 of a departure as far as reducing waiting by schedule frequency is concerned.

The demand curve was calculated for 243 markets among the 23 cities involved. Demand growth through time was provided by FAA projections, as shown in Table B-2.

TABLE B-2

Passenger Enplanement Growth Factors
1975-2000

| YEAR | GROWTH FACTOR |
|---|---|
| 1975 | 1.00 |
| 1985 | 1.74 |
| 1990 | 2.07 |
| 1995 | 2.51 |
| 2000 | 3.02 2/ |

2/ This is roughly a 4.5 percent growth rate, compounded.

B.1.4 FA-4 Summary

The fleet routing model was used to predict the response of the airline system to growth in passenger traffic demand. Routing, aircraft size, and frequency decisions of airlines was predicted in the face of passenger demands representing 1975 to 2000. The 1974 dollars were used for fares and costs. In addition, the degree of competitive scheduling in existence in 1974 was continued unchanged. The projected fleet routings took advantage of larger aircraft, direct routings, and increased frequency to accommodate future increases in demand. The program produced information on total activity at each airport. In addition, the frequency of nonstop flights between each city pair was produced as an input to the time of day scheduling program, SKEDGEN, described in the following section of this appendix.

B.2 Description of Airline Schedule Generation, SKEDGEN

An airline scheduler generally knows how many flights he has between each city pair in his network. Likewise, he knows when he would schedule each of those departures if he had no outside constraints. He would schedule one or two flights at each time of peak demand, and space the rest through the day with wide spacing at times with less demand. His constraint is the limited fleet of aircraft available. This forces the scheduler to move some flights earlier so that the aircraft can arrive in time for a departure, and to delay other departures so that an arriving aircraft has time to unload and load.

This is what SKEDGEN does. SKEDGEN is an automated airline scheduler. It starts with a set of nominal departure and arrival times. About each time is a "window," which is the amount of repositioning that is permitted. The "window" is narrow at peak hours but wide during the midday lulls. SKEDGEN uses simple heuristic trials to get flights to interconnect neatly. First, all the arrivals and departures at one airport are considered. Attempts are made to move departures back and arrivals up so that one airplane can serve both. This is done as long as it does not undo a match at some other airport. Once the first airport is finished, SKEDGEN moves on to the next until it has exhausted the list.

The result is a simulated Official Airline Guide; that is to say, a timetable of arrivals and departures for the whole system. Also of interest is the minimum number of aircraft needed to do the job. But the key output, the one important for delay calculations, is the time of day history of aircraft activities at each airport. This gives the amount of peaking at the airport, which is important in calculating the delays.

The inputs to SKEDGEN are two. The first is the output from FA-4, the city pair nonstop frequencies. Multistop flights must be broken up into component nonstops for this exercise. Also, no degree of head to head competitive scheduling is created. Competition is manifested only by the higher competitive frequencies predicted by FA-4.

The second input is the time of day passenger demands. These histograms, derived empirically define the desired departure times of the passengers. There is one for short haul and

North-South markets. Then one each for medium, long, and continental distances, east and westbound. These histograms were developed by examining 1974 time of day seat departure patterns in several markets and applying a certain amount of correction for load factors and a degree of smoothing. Typical histograms for eastbound and westbound 1,200 mile markets are shown in Figure B.1.

SKEDGEN distributes the frequencies in a city pair market so that each flight serves an equal fraction of the time of day demand. This spaces more flights in the peak and less in the off-peak hours. Half the travelling day is included in the total windows for all departures. Thus, high frequency service has small windows for each flight, while lower frequency service is more flexible. The size of each window in a given city pair is the same percent of the demand histogram; thus, short windows in peak hours and longer spaces in the off-peak.

The result of a SKEDGEN run is a histogram of activity through the day at each airport in the 23-city network. Figure B.2 is an illustration for Boston, forecast year 2000.

In the case where peak-hour pricing applies, the departures in each market which enter or leave the particular airport are spaced evenly through the travelling day. Windows are all of equal size, producing a moderately smooth schedule of activity through the day at the peak priced airport.

## B.3 Airport Delay Calculations

Illustrations of the concept of airport quotas (Figure 4.1) assume a single airport capacity. Actually, airports have up to eight capacities operating at different times. The most basic split is between the VFR capacity and the more limited capacities under IFR conditions. The other split is between operations using the normal duty runways and operations using runways designed for occasional use when wind direction and speed prohibit the usual airport configuration. Under IFR conditions and with unfavorable winds the capacity can be half that of the VFR fair wind conditions. With the introduction of hardware to detect wake vortex dissipation, it is possible to operate at lower separations and thus increase capacities somewhat over half the time. This adds yet another dimension to airport capacities.

By way of example, the case of Boston's Logan Airport can be examined. Under existing conditions the capacities are:

| | IFR | VFR |
|---|---|---|
| NORMAL | 53.9 | 111.3 |
| CROSSWINDS | 50.3 | 89.8 |

The operating percentages are approximately:

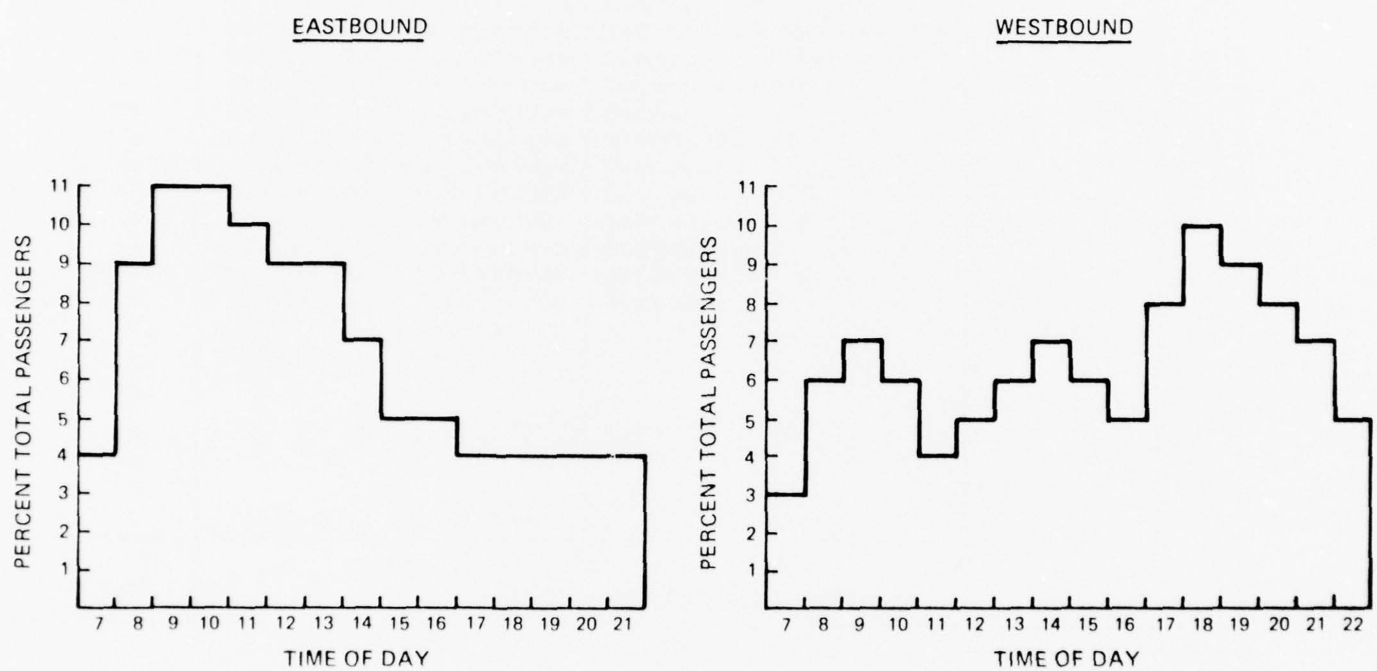
| | IFR | VFR |
|---|---|---|
| NORMAL | 8% | 63% |
| CROSSWINDS | 8% | 21% |

With upgraded third equipment, the matrix becomes three dimensional:

WAKE VORTICES

| NO WAKES VORTICES | IFR | | VFR | |
|---|---|---|---|---|
| | | 66.8 | | 129.6 |
| NORMAL | 82.1 | | 135.9 | |
| | | 58.3 | | 97.0 |
| CROSSWINDS | 58.9 | | 107.0 | |

FIGURE B.1
TIME OF DAY PASSENGER TRAVEL PREFERENCES
1200 MILE MARKETS



## FIGURE B.2
## TIME-OF-DAY AIRCRAFT MOVEMENTS AT BOSTON, YEAR 2000

| TIME OF DAY | NUMBER OF ARRIVALS AND DEPARTURES | | | | |
|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 |
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | DDDDDDADD | | | | |
| 8 | DDDDAAADDD | DADDDA | | | |
| 9 | DDDDAADAAD | DAADDADADD | DAADDDDA | | |
| 10 | DDDAADADDD | AAADAADADD | DADAAAADDD | A | |
| 11 | DDAAADDDAD | DAAADDAAAD | DDDAADDDAD | | |
| 12 | DAAAADDAAD | AAADADDAAA | ADDAADAADA | A | |
| 13 | DDADADADAD | AAADDAAAAD | DDAAADA | | |
| 14 | DADAAADDAA | DADDDAAADA | AADDDDD | | |
| 15 | DAAADDDDAD | DADDADDAAA | AAADDAADD | | |
| 16 | AAADAADDAA | ADDDAAAAAA | DDDDA | | |
| 17 | DDDAADAADD | AADDDDAADD | DAAADDAAAD | A | |
| 18 | DDAADDDDAA | ADDDAAAAAA | DDDADDADDA | DAA | |
| 19 | DDAADDDDAA | DDDAAAAAAD | DADAADDDAD | DADAAADDDA | |
| 20 | DAADDDDDAA | DDDDAAAAAD | DAADDDADDA | A | |
| 21 | AADDAADAAD | AADDAAAAAD | DDDA | | |
| 22 | ADDDAADAAA | AAA | | | |
| 23 | DDAADAADAA | A | | | |
| 24 | AAAA | | | | |

28 OVERNIGHTING AIRCRAFT

A: ARRIVAL
D: DEPARTURE

The percentages are:

| WAKE VORTICES | IFR | VFR |
|---|---|---|
| NO WAKE VORTICES | | |
| NORMAL | 2% / 6% | 40% / 13% |
| CROSSWINDS | 2% / 6% | 8% / 5% |

Each airport, then, has several capacities, typically at least IFR and VFR. It was assumed that airlines would schedule movements in excess of IFR capacities during IFR weather. Two dimensions, therefore, were used to describe airport congestion: one is the per operation or total delay minutes; the other is the percent of movements that must be cancelled on an annual average basis. These cancellations replace delays of impossible lengths. Otherwise the annual delays would be meaningless sums of large and impractical numbers. If daily delays at one capacity exceed 20 minutes average per operation (40 minutes per flight), then sufficient cancellations were postulated to reduce congestion to a 20 minute average delay level.

The histogram of departures and arrivals produced by SKEDGEN (see Appendix Section B.2) was examined for each airport. These movements represented only the services among the 23 cities, however. To reflect the rest of the demand, the ratio of total air carrier operations to the operations among the 23 cities was calculated for each airport from the OAG schedule (April 15,1975). This was used to inflate the predicted SKEDGEN activities to represent the full air carrier activities. Since SKEDGEN predicted airport activity patterns reasonably well for 1974, it was assumed this method would continue to be valid for future years.

The full air carrier histogram was examined for number of peaks and the percentage of the traffic in the peak hour. This categorization allowed the delays and cancellations to be calculated using a technique based upon advanced queuing theory. 3/

3/ For a description of this program, the reader is referred to "Time Dependent Estimates of Delays and Delay Costs At Major Airports," Hengsbach and Odoni, Massachusetts Institute of Technology, January 1975.

The delays and cancellations were predicted at each of the two to eight hourly capacities applicable to the airport in question. Then, the results were averaged according to the prevalence of each of the capacities. This produced an annual average delay and cancellation rate for the planning year. Results of this process, aggregated over the airports in the 23 hub network, are shown in Figures 4.3 and 4.4.

# APPENDIX C

## ILLUSTRATIVE FLOW CONTROL BENEFITS VALUATION

## APPENDIX C

### ILLUSTRATIVE FLOW CONTROL BENEFITS VALUATION

As discussed in Chapter 3, because of fuel savings, the cost of aircraft delay is lower when delay is encountered on the ground with engines off than when encountered with engines in operation (either on the ground or airborne). While the technical ability of the UG3RD flow control feature to shift delays to a wait on the ground with engines off is still undetermined, it is possible to provide an estimate of the order of magnitude of potential savings that might be obtained from this feature.

To estimate the potential magnitude of fuel savings, it is first necessary to estimate the relative proportions of total aircraft delay minutes which are associated with individual aircraft delays of a given duration. Such a distribution was developed for 23 terminals and the system as a whole from 1974 delay data obtained from Eastern Airlines. The distribution of systemwide delay by length of individual aircraft delays is given in Table C.1.

The second step in estimating potential fuel savings from flow control was to make assumptions about the ability of flow control to project and shift individual aircraft delays of a given length to a wait on the ground. In this study, it was assumed that flow control would have the following projection and shift capabilities:

1. From 1975 to 1980, flow control will shift all aircraft delays in excess of 60 minutes.

2. From 1981 to 1985, flow control will shift all aircraft delays in excess of 30 minutes.

3. From 1986 to 2000, flow control will shift all delays over 15 minutes.

Finally, estimates of total terminal delay that would exist for each year in the span 1976 through 2000 were divided into subcategories of individual aircraft delay using the relative distribution described in step one above. These distributions were then compared with the assumed ability of flow control to shift aircraft delays of various lengths to a wait on the ground to determine total aircraft delay minutes shifted.

Total aircraft delay minutes shifted were than multiplied by appropriate average aircraft fuel cost per minute and discounted to estimate the order of magnitude of potential savings from the institution of flow control.

As indicated above, however, estimates obtained from this procedure only illustrate the order of magnitude of flow control savings. The statistics are the result of assumptions about the ability of flow control to shift delay. These assumptions are made without further analytical verification. For this reason, illustrative values of flow control savings are presented, but are not included in the calculation of total system benefit-to-cost ratios.

TABLE C.1

Distribution of Total System Terminal Area Delay by Length of Individual Aircraft Delays

| Length of Individual Aircraft Delays (Minutes) | Percent of Total System Delay |
|---|---|
| 4.0 | 17.9 |
| 4.1 - 15.0 | 51.9 |
| 15.1 - 30.0 | 18.4 |
| 30.1 - 60.0 | 8.8 |
| 60.0 | 2.9 |
| | 100.0 |

Table C.2 provides estimates of the value of fuel savings that would be achieved under various alternative UG3RD configurations assuming that the flow control feature of automation can shift aircraft delay as assumed above. These savings, which are not included in the value of delay reduction benefits given in Table 3.8 and described in Section 3.3.2 would total $1.3 billion for Configuration 1 and $601.9 million for Configurations 2 through 5 over the period 1976 through 2000. Smaller savings attainable from the latter configurations are due to the fact that the total aircraft delay which would occur in these situations is less than under Configuration 1. Thus, less delay can be shifted to an engine-off situation.

Because a strong technical evaluation of the ability of flow control has not been completed, results reported here are based on assumed degrees of effectiveness. The savings have been excluded from the calculation of cost-benefit ratios.

TABLE C.2

Present Value of Fuel Savings
from Assumed Delay Shifts due
to Flow Control
(millions of $)

| Period | UG3RD Configuration 1 | UG3RD Configurations 2-5 |
|---|---|---|
| 1980 | $ 9.3 | $ 6.7 |
| 1985 | 36.4 | 17.6 |
| 1990 | 80.8 | 36.4 |
| 1995 | 84.6 | 34.5 |
| 2000 | 79.6 | 29.9 |
| 1976-2000 | $1,362.4 | $601.9 |

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